Sorghum value chain analysis in Ghana

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Notwithstanding the above, we state that the conclusions, views and recommendations stated in this report are those of the authors and do not necessarily represent the views of EC DEVCO or the EU Delegation in Ghana.

ACRONYMS

AEA	Agricultural Extension Agent
BOG	Bank of Ghana
CSIR	Council for Scientific and Industrial Research
CF	Commercial farms
DEVCO	European Commission's Directorate-General for International Cooperation and Development
DFID	Department for International Development
DRC	Domestic Resource Cost ratio
EC	European Commission
ECOWAS	Economic Community of West African States
EDF	European Development Fund
EPC	Effective Protection Coefficient
EUD	European Union Delegation
FBO	Farmer based organisation
FDA	Food and Drugs Authority
FGD	Focus group discussions
FRI	CSIR Food Research Institute
GAP	Good Agricultural Practice
GEPA	Ghana Export Promotion Authority
GGBL	Guinness Ghana Brewery Limited
GhAIP	Ghana Agricultural Investment Plan
GHS	Ghana Cedis
GIZ	Deutsche Gesellschaft fuer Internationale Zusammenarbeit (German Agency for International Cooperation)
GLSS	Ghana Living Standards Survey
GN	Groundnuts
GoG	Government of Ghana
GSA	Ghana Standards Authority
GSS	Ghana Statistical Service
GWP	Global Warming Potential
Ha	Hectare
IC	Intermediate consumption
ICT	Information and Communication Technology
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILO	International Labour Organization
Km	Kilometre
KNUST	Kwame Nkrumah University of Science and Technology, Kumasi
LCA	Life Cycle Assessment
LG	Local Government
LMF	Lead and medium-scale farmers
LUSPA	Land Use and Spatial Planning Authority (previously TCPD)
MADE	Market Development Programme for Northern Ghana

MOAP	Market Oriented Agriculture Programme
MoFA	Ministry of Food and Agriculture
Mt	Metric tonne
NASH	Non-aggregator linked smallholder farmers
NDA	Northern Development Authority
NGO	Non-Governmental Organisation
NIP	National Indicative Plan
NOP	Net Operating Profit
NPC	National Protection Coefficient
NPK	Nitrogen, Phosphorus, Potassium
NR	Northern Region
NRI	Natural Resources Institute, University of Greenwich
NSEZ	Northern Savannah Ecological Zone
OVCF	Outgrower and Value Chain Fund
PFJ	Planting for Food and Jobs Programme
SADA	Savannah Accelerated Development Authority
SARI	Savannah Agricultural Research Institute
SHF1	Smallholder farmers (category 1)
SHF2	Smallholder farmers (category 2)
SME	Small- and Medium-scale Enterprise
SRID	Statistics, Research and Information Directorate, MoFA
UDS	University of Development Studies, Tamale
UER	Upper East Region
UK	United Kingdom
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
US$	United States Dollar
UWR	Upper West Region
VA	Value Addition
VAT	Value Added Tax
VC	Value Chain
VCA4D	Value Chain Analysis for Development
VGGT	Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security
VSLA	Village Savings and Lending Association

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EXECUTIVE SUMMARY

This Sorghum Value Chain Analysis has been undertaken in Ghana as part of a number of studies commissioned under the Value Chain for Development (VCA4D) Project, a project funded by the European Union (EU) and implemented by Agrinatura, with the objective of generating evidence-based information for policy actions. The European Union Delegation (EUD) in Ghana, in partnership with the Government of Ghana (GOG), selected the sorghum value chain, which along with the groundnuts value chain, are priorities for the Ministry of Food and Agriculture (MOFA). The study included two field missions during which extensive consultations were held with a wide range of stakeholders. Below is a summary of the main findings.

Overview of sorghum value chain

Prioritisation of the sorghum value chain is based on its importance as a food security crop and the potential to scale up processing of the grain, thereby generating significant value added in the chain. Sorghum is a highly resilient drought tolerant food crop. Its production is concentrated in the Northern Regions of Ghana, which is usually drier than the South and is reported to have recorded a 15% decline in average annual rainfall in the past decade compared to the previous 30 years. Official data indicates that the country as a whole is generally becoming drier but the average reduction in annual rainfall across the country is far less steep than in Northern Ghana - estimated at 8%. Hence, promoting sorghum cultivation is seen as an important climate-resilience strategy.

Sorghum has important nutrition benefits. For instance, it contains no gluten-forming proteins, thus making it safe to be consumed by people suffering from coeliac disease, or those allergic and intolerant to wheat, rye and barley. It also contains varying quantities of essential minerals such as potassium, phosphorus and magnesium. However, in most developed countries, including especially in the US, it is mainly used as a feed for livestock but in Ghana it is consumed as food or brewed into traditional low-alcohol beer.

Sorghum has considerable potential as an industrial crop. Currently, the sorghum grain transformers (mainly pito and industrial brewers) account for about 42% of total value added in the chain, compared to the total contribution of 26% by grain producers and distributors (e.g. aggregators and traders). In contrast, processors in the groundnuts value chain contribute only 30% of total value added in that chain. Sorghum production has, however, been rather erratic over the past decade, being generally outperformed by all other cereals subsectors cultivated in Northern Ghana. Options to turn around this performance have been explored in this study.

Total sorghum grain output in 2018 is estimated at **278,000 tonnes**. The production, transformation and marketing of the sorghum grain and products through three main sub-chains, which are briefly described below and depicted in Figure ES-1:

Sub-chain 1: This sub-chain mainly serves the rural communities in which sorghum grain production is concentrate. The sorghum grain output utilised in this sub-chain is mainly consumed by farm households and/or used by rural pito brewers. Production is dominated by smallholder farmers who generally use very little or no yield-enhancing inputs (e.g. improved seed, fertiliser and pesticides) and are designated in this study as **SHF1** farmers. The SHF1 farmers usually sell directly to other households in the rural areas as well as to artisanal pito brewers.

Sub-chain 2: This sub-chain targets mainly urban consumers. In addition to production by the SHF1 farmers there is a group of smallholder farmers in this sub-chain who receive support from large-scale aggregators or commercial farmers to cover 20% of their inputs needs for sorghum cultivation. These farmers are relatively more productive and are designated by the team as **SHF2**. Part of their grain output is aggregated by large-scale aggregators who supply to an industrial brewery (GGBL) under contract. The large-scale aggregators are assisted by Lead Farmers (LF) who interface with the SHF2 – mobilizing them, monitoring their activities in order to ensure repayment of inputs credit and bulking produce on behalf of the aggregators. This segment of the sub-chain has emerged largely due to entry by the industrial brewery into the sorghum grain market. Sale to the mainstream urban market involves aggregation by micro-scale rural collectors and small/medium-scale aggregators who deliver to urban wholesalers and through them to urban retailers trading in grains. Other actors who are important in this sub-chain include inputs suppliers, agriculture extension staff, transporters and organisations financing the provision of inputs credit by the large-scale aggregators (see Box 3.1).

Sub-chain 3: This sub-chain has emerged principally because of the initiative by the industrial brewery to substitute imported barley with locally-produced sorghum grain for industrial brewing of beer and other non-alcoholic beverages. Grain production in the sub-chain is by SHF2 farmers, lead (or nucleus) farmers, medium-scale farmers and commercial farmers. Large-scale aggregators are key players in the sub-chain as are inputs suppliers, agriculture extension personnel, financial institutions, transporters and storage services providers. Though the volume of sorghum grain currently utilized in this sub-chain is rather low, its potential to drive growth and transformation of the value is apparent. It is for that reason that attention is paid to Sub-chain 3 in the analysis.

It is estimated that about 38% of the total sorghum grain produced in Ghana is utilized in Sub-chain 1 whilst 43% of the grain is used in Sub-chain 2. In the newly emerging Sub-chain 3 the sorghum grain utilized represents about 7% of total output. Postharvest grain losses in the sub-sector accounts for about 12% of total production.

Evidence generated in this study show that the sorghum value chain in Ghana is economically, socially and environmentally sustainable, except for environmental issues related to land use and land use change in relation to sub-chain 1 (referred to rural pito) and sub-chain 2 (referred to urban pito), impacting mainly on the ecosystem quality and human health domains[1]. This evidence is discussed below along with exploration of options which can contribute to the transformation of the value chain.

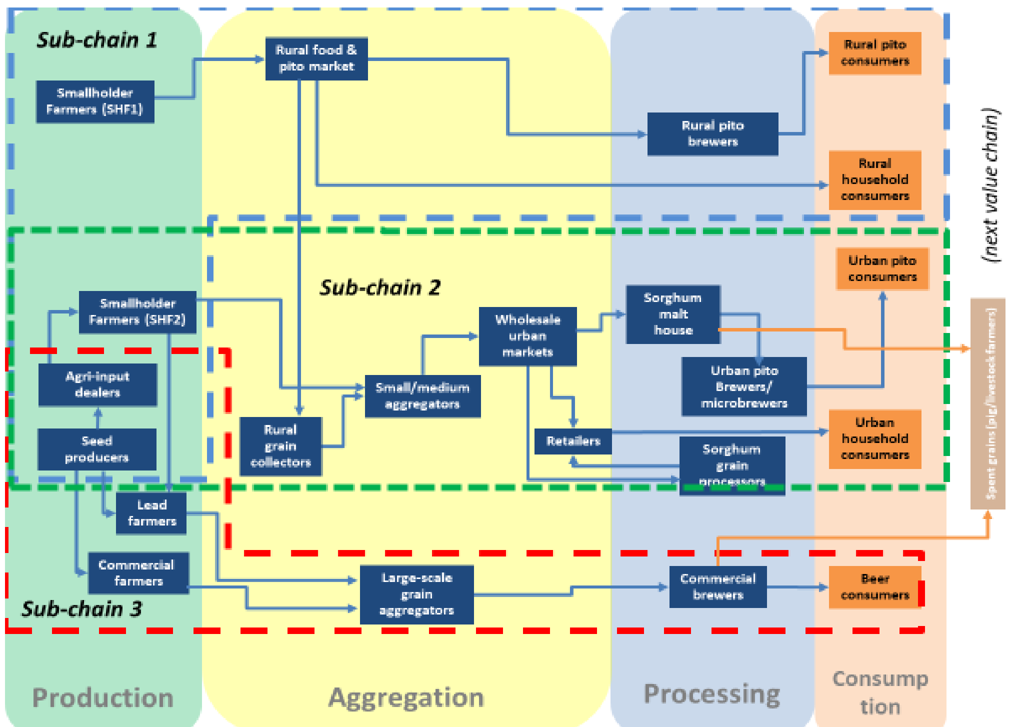

Figure ES-1: Typology of key actors and functions in Sorghum Value Chain in Ghana

Economic contribution and sustainability of the sorghum value chain

The main findings from the economic analysis undertaken during the study and reported in Chapter 4 are summarised in Table 4.7. From the financial analysis reported in Section 4.2, it emerged that the operations of all actors in the sorghum value chain are profitable, from grain production through distribution and marketing to transformation in consumer products as pito and, more recently, beer and other non-alcoholic beverages from an industrial brewery.

There is only one group of actors who are currently not able to generate annual income above the national poverty line from exclusively producing sorghum grain. These are the low-input, low-productivity smallholder farmers (categorised in this study as SHF1). They are unable to access yield-enhancing inputs such as fertiliser and pesticides under the GOG's Planting for Food and Jobs (PFJ) programme and therefore obtain extremely low yields – estimated

[1]*The main environmental hotspot detected within the value chain are: (i) a potential damage to human health associated mainly with high levels of global warming potential due to forest degradation and firewood combustion, alongside (ii) damage to ecosystems due an extensive land use –associated mainly with low grain yields– and to land use change and forest degradation –triggered by firewood use for pito brewing–.*

at 0.65 tonnes per hectare. This is largely because they lack the means to pay for the inputs which are subsidised 50% by GOG. From consultations with the actors, it is apparent that they are constrained not so much by price but rather by household illiquidity at the time of planting. The sorghum-based income SHF1 farmers obtain is estimated at GHS 215 (equivalent to $45 or €40) per annum per farmer. This income is generated from committing only 30% of the land they cultivate with sorghum; the remainder being planted with maize (50%) and other crops (20%). Assuming they planted only sorghum, their estimated annual farm income will be GHS 715 ($149 or €132), which is 45% below the national poverty line (estimated at GHS 1,315 in 2017[2]) and far below the annual national minimum wage, which is about GHS 3,065 ($640 or €565). Hence, crop diversification appears to be a good strategy to mitigate the potential risk of income, and possibly, food insecurity which these farmers face.

Their counterparts, the emerging smallholder farmers (SHF2), who receive pre-financing support from aggregators and commercial farmers, are able to acquire the inputs and are able to record over 25% increase in yield and double the annual income generated per household from sorghum. The support provided to the SHF2 farmers tends to be funded through schemes such as the MOAP-supported Inputs Revolving Fund in the Upper West Region and the Outgrower and Value Chain Fund (OVCF) in the Upper East (see Box 3.1 in Chapter 3). The inputs credit support to these farmers is usually limited to only 20% of their requirements. The annual income obtained by SHF2 farmers from sorghum production is estimated at GHS 620 (or $129 or €115). Again, if they produced only sorghum, it is projected that they will earn about GHS 1,545 ($322 or €287) per annum, which is above the national poverty line.

Value added in sorghum value chain

The value chain in 2018 generated total value added estimated at GHS 1,016 million, which is equivalent to almost US$211.2 million or €188 million and represents 0.3% of Ghana's gross domestic product (GDP) and almost 2.0% of the overall agricultural GDP in Ghana. Breakdown of actors' contribution to total value added is as below:

- Grain producers – 18%;
- Grain distributors such as rural collectors, aggregators, wholesalers and retailers – 8%;
- Sorghum transformers, e.g. pito and industrial brewers as well as grain processors – 42%;
- Suppliers of intermediate goods and services to the main value chain actors – 32%.

Sorghum VC contribution to public finances, foreign exchange generation and employment

The chain is a net contributor to public finances in Ghana, providing about GHS 159 million (i.e. $33 million or €29.4 million) per annum in the form of taxes and local council levies. This figure is net of the inputs subsidies under PFJ, which is estimated at GHS 6.7 million. The subsidies represent only 4% of the gross tax revenues from the value chain. As mentioned above, one of the key targets of the PFJ, the SHF1, appear not to be benefiting.

About $41.2 million (i.e. €36.7 million), is spent on imported intermediate goods and services within the chain but only trace volumes of sorghum grain is reportedly exported into regional markets. One key recent development is the use of sorghum grain as a local raw material in brewing by the industrial brewery. This is saving about $7.6 million (€6.6 million) which would otherwise have been used to import malt barley by the brewery.

The value chain creates over 180,000 self-employment opportunities for smallholder farmers as well as people engaged in sorghum grain distribution (collectors, aggregators and retailers). There are also over 5,500 self-employed pito brewers, in an industry which employs about 15,000 low-wage workers, almost all women. These "workers" actually take advantage of the employment to accumulate start-up equity for their own pito brewing enterprises. There is evidence that new low-wage, temporary ("by-day") labour employment opportunities have emerged along with more permanent and better-remunerated jobs as a result of commercial sorghum cultivation and grain aggregation.

Economic sustainability of the sorghum value chain

The value chain is well-integrated into the local economy as shown by its estimated rate of integration of 0.78. The domestic resource cost (DRC) ratio in the chain is also estimated at 0.35, which is well below unity (i.e. <1) and indicates that it has a comparative advantage and is viable within the global economy. The nominal protection coefficient is 1.1, an indication that players in the chain currently enjoy a certain level of protection. The value chain is also highly inclusive as evidence generated through this study shows that most of the income generated in the

[2] Source: Ghana Statistical Services (2018) "Ghana Living Standards Survey Round 7: GLSS7 – 2005-2017).

chain accrues to small and micro-scale actors including smallholder producers (especially the SHF2), small/micro-scale grain collectors and retailers as well as pito brewers.

Fostering rapid and inclusive growth in Ghana's sorghum value chain

The study explored various options which can contribute to rapid and inclusive growth in the sorghum value chain, including actions to boost yields obtained by smallholder sorghum farmers. The main option explored involves supporting smallholder farmers with credit in order to enable them acquire yield-enhancing inputs which are available under the Government's flagship programme – Planting for Food and Jobs (PFJ). In addition, the farmers need to be encouraged to adopt better postharvest handling practices, including drying the grains using tarpaulin. This will make it possible to reduce postharvest losses in the sorghum value chain to levels consistent with the Government's commitments under the Malabo Declaration (2014). These options were explored because they have already been demonstrated to have positive impact on grain output and marketable volumes, especially among SHF2 farmers. Alternative agroecological solutions could not be explored because of absence of cases in the sorghum value chain which would have made it possible to estimate impact on yields in the specific context of Northern Ghana.

It is projected that by boosting yield and reducing postharvest losses the volume of sorghum grain available for sale by smallholder households will increase by about 30% whilst average food available to be consumed by the households also rise by over 40% (from 8.5 bags to about 12 bags per household). The sorghum-based income of SHF1 farmers is also likely to almost double to about GHS 412.50 (equivalent to $86 or €76), which translates to about GHS 1375 ($285 or €255) if they cultivated only sorghum rather than the current practice of allocating only 30% of their cultivated land to the crop. This farm income is above the national poverty line (estimated at GHS 1,315 in 2017), implying that these actions have the potential of moving SHF1 farmers out of poverty. For SHF2 farmers it is projected that their household income from sorghum production will rise by about 30% to GHS 800 (i.e. $165 or €150) per annum at current levels of allocation of cultivated land to sorghum. We project that if they commit 100% of their area planted to sorghum with the extra support proposed, they can obtain about GHS 2,000 ($415 or €370) per annum.

Growth in offtake needed to sustain increased farm productivity

Improved offtake capacity is essential in sustaining output and productivity growth in the sorghum value chain. The options explored include the following:

- Promoting energy-efficiency in pito brewing by encouraging pito brewers to adopt more energy-efficient stoves. The technology is already available and at relatively low-cost, with the potential for cost-recovery within one and two years.
- Effective marketing of non-alcoholic pito. This is necessary because of the difficulty in differentiating between alcoholic and non-alcoholic pito. It causes concerns, especially among religious leaders, that promoting consumption of the latter can easily lead to increase in drinking the alcoholic pito and a rise in alcoholism in the communities.
- Encouraging uptake sorghum in other breweries, including for example the Accra Brewery Limited (ABL) as well as by microbreweries. The latter will promote the emergent microbreweries through access to low-cost start-up capital as it is a new industry;
- Fostering sorghum grain processing by enabling the micro-scale processors to scale up their operations. The two main challenges facing these processors is lack of start-up capital which enables them to invest in physical processing infrastructure which is compliant with Government regulations. There is evidence showing that this hurdle can be overcome through schemes such as public or donor-funded incubation hubs which provide access to facilities that meet relevant licensing and regulatory requirements on a time-bound basis (usually between three to five years).
- Supporting upscaling of the emerging modern grain aggregation and distribution segment in the sub-chain 3, especially supporting the large-scale aggregators to invest in suitable storage and grain handling facilities.

We project that total value added generated in the value chain as a result of the combined effects of the proposed interventions will increase by almost 65% to about GHS 1.67 billion (equivalent to just over US $345 million or €310 million). Assuming the same base as in 2018, this figure will represent a contribution to agricultural sector GDP of about 3%. Along with the rise in value added is an over 40% increase in wage earnings attributable to the sorghum value chain and 61% increase in fees for provision of financial services to actors in the chain, including outside suppliers. Though total subsidy injected into the chain via the PFJ rises more than three times, the net increase in contribution to public finance is more than 30%. This is due largely to a 37% rise in total contributions to taxes, duties and local council levies by actors in the value chain. Income accruing to the main actors, that is excluding suppliers of goods and services, is projected to increase by an estimated 64%. The anticipated growth is also highly inclusive and socially sustainable. The total share of actors' income which is obtained by small and medium-scale actors is close to 80%. These include smallholder famers, micro, small and medium-scale aggregators as well as pito brewers, who are predominantly women.

Social sustainability of the sorghum value chain

The following graph provides a picture of the main social consequences of the VC activities in 6 strategic domains.

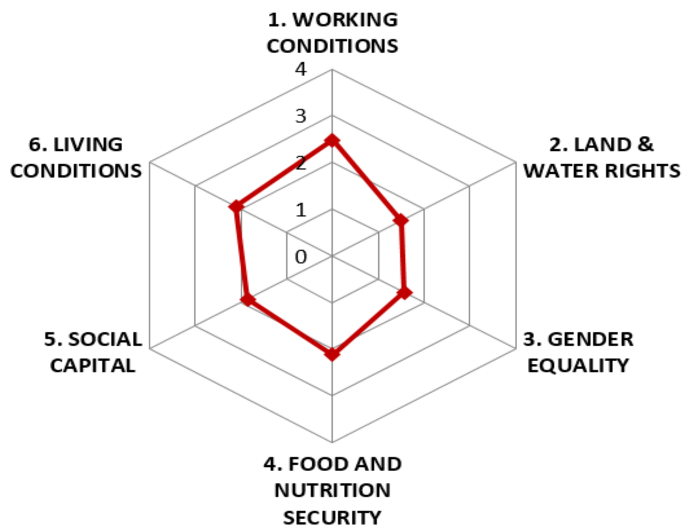

Figure ES-2: Social profile

The value chain is socially sustainable. As a cash crop, the value chain offers opportunities for small-scale farming as well as small/medium-scale enterprises involved in grain marketing, pito brewing and sorghum grain processing. There are also several SMEs supplying various intermediate goods and services including agro-inputs dealers, tractor service operators, grain transporters etc. During the study we found evidence of the youth engaging in sorghum grain production as SHF2 farmers linked to large-scale aggregators and commercial farmers with outgrower schemes. Rural employment for, especially the youth, is growing where the large-scale aggregators and commercial farmers operate. The majority of them are being employed on an informal, casual or temporary basis. The main concern is about employment security for the rural workforce who are engaged in the newly emerging sub-chain 3. This sub-chain, which is illustrated in figure ES-1 above (*Typology of key actors and functions in Sorghum Value Chain)*, targets supplies to the industrial brewery and involves actors such as commercial farmers and large-scale aggregators. In contrast with the other two sub-chains described in Section 3.2.1, the sub-chain 3 is more formalised and enforces quality standards stipulated by the Ghana Standards Authority (GSA) as well as standard measures which ensure that trade is based on transparently determined weight rather than volumetric measures (e.g. traditional bowls such as "olonka"). Trade between the industrial brewery and aggregators as well as commercial farmers is also based on contracts unlike in the informal sub-chains 1 and 2. Sub-chain 1 targets mainly pito brewers and household consumers in rural areas whilst sub-chain 2 targets the urban market.

The risk, however, is that if for whatever reason the commercial brewer scales down utilisation of sorghum in brewing it will have significant implications for jobs and income security in the sorghum-producing communities in Northern Ghana. This is validated in Section 7.4 with analysis of the impact COVID-19 is having on the sorghum value chain. The analysis shows that the industrial brewery reduced sorghum grain utilisation by 40% in response to slump in demand for its products due to the pandemic and the measures instituted by government to contain its spread. SHF2 farmers supplying through aggregators to the industrial brewery have experienced short-term liquidity constraints due to delays in payment as offtake has slowed down. This can lead to lower uptake of inputs in the 2020 planting season and possibly subsequent seasons unless the formal grain market recovers. Another short-term impact is possible 17% reduction in total value added in the value chain and decline in its contribution to public finances by almost 29%.

The sorghum value chain contributes to inclusive growth through the involvement of three groups of participants and beneficiaries: small scale producers who produce relatively small quantities on small plots of land (accounting for about 95% of total production), the pito-brewers and a workforce that supports the system of production, trading and processing. Women in particular benefit from employment opportunities as they carry out most of the tasks associated with production and the traditional processing. Both, men and women gain a degree of financial independence from their involvement in the VC. Returns from small-scale production benefit the local economy and are invested in children's education, health care, housing, small businesses and in the farm.

However, sorghum can contribute much more if risks and challenges identified in the chain, which are discussed in depth in Chapter 5, are addressed. These include the following:

i) Lack of effective smallholder farmer groups and power imbalances between VC actors – this is for instance evidenced by the rather marginal involvement of farmers in negotiating producer prices for the grains sold to the industrial brewery;
ii) Low farm labour wages and harsh or rather hazardous working environment, including for pito brewers;
iii) The land tenure system;
iv) Gender inequality (no access to land and credit and low decision power);
v) Health care availability and affordability; and
vi) Lack of investment in vocational training.

In Chapter 7, the potential impact of specific improvements in the value chain are simulated. The results show that increased productivity of sorghum can be socially, economically and environmentally beneficial as well as sustainable for all VC actors. The specific actions explored and recommendations which emerged are summarised below.

Environmental sustainability of the sorghum value chain

The LCA study of sorghum-based products in Ghana provides an up-to-date reference regarding their environmental performance and allows to identify hotspots and margins for improvement for all three sub-chains. In order to answer the framing question, "*Is the VC environmentally sustainable?",* it is broken down into three core questions, focused on the potential impact of the VC in terms of the following three domains:

a) human health; b) ecosystem quality; and c) resource depletion (for which the endpoint results of the ReCiPe 2016 method are used).

The environmental analysis within Sub-chain 1 was carried out for *pito* production and within Sub-chain 2 for beer produced at small, semi-industrial scale. For Sub-chain 3, LCA was carried out for beer produced at industrial scale. Within Sub-chains 1 and 2, alongside pito, milled grains for household consumption are also produced. Impacts of grain milling are negligible, therefore environmental impacts of milled grains are assimilated to those of grain production at farm gate.

Considering the environmental impacts according to the above three domains, impacts on human health contributes to the overall impacts by 53% in Sub-chain 1 (pito) and by 27% and 76% in Sub-chain 2 and 3 respectively (micro-brewing and industrial brewery). Impacts on ecosystem quality contributes to the overall impacts by 47% in Sub-chain 1 (pito) and by 72% and 23% in Sub-chains 2 and 3 respectively. Impacts on resources depletion are negligible since very few quantities of materials and of energy inputs are required in the studied sub-chains. They contribute to the overall impacts by 0.04% in Sub-chain 1 (pito) and by 1.2% and 1.7% in Sub-chains 2 and 3 respectively.

Considering the overall environmental impacts within each sub-chain, it is worth noting that the total impacts of pito is almost threefold compared to those of the other two sub-chains. In terms of contribution to the overall impacts within a given Sub-chain, the analysis showed that in Sub-chain 1 impacts on human health and on ecosystem quality are the highest; their contribution to the overall impacts are 53% and 47% respectively. In sub-chain 2, the largest contribution to the overall impacts is represented by potential damages to ecosystems (72% of the overall impacts), while in sub-chain 3, potential impacts on human health contribute to the overall impacts by 76%.

For pito brewing, the main hotspots are firewood use, associated with forest degradation and subsequent changes in land use. Indeed, potential damage to ecosystems due to forest degradation triggered by firewood use, along with low grain yields and, secondarily, a relatively low conversion rate of grains to *pito*, prevents Sub-chains 1 and 2 (referred to urban pito alone) from being environmentally sustainable. This is also true for the potential damage to human health associated mainly with high levels of global warming potential derived from the use of firewood. Therefore, the introduction of improved brewing technologies involving the use of ovens for *pito* brewing with reduced use of firewood can have very positive impacts both from human health[3] and ecosystem quality perspectives. Indeed, such improvement would contribute to the reduction of firewood consumption, of direct exposure of brewers to harmful open fire pollutants and to the reduction of forest degradation.

The environmental sustainability of the part of the Sub-chain 2 linked to microbreweries is in line with what can be expected for a small-scale brewery. The use of locally produce sorghum grains for brewing showed to be environmentally sustainable, although to promote further improvements in the environmental profile of this Sub-chain, a more efficient land use should be sought, which could be possible by improving grain yields.

Regarding Sub-chain 3, a comparison is proposed showing differences between environmental performances of brewing with locally produced sorghum grains and with barley malt of EU origin. The results of the analysis show that the potential environmental impacts of brewing with sorghum from Northern Ghana does not differ significantly from those derived from brewing with imported barley malt, which allows to conclude that the sub-chain has an overall acceptable level of environmental sustainability.

For all three sub chains, alternative scenarios are proposed; these are energy (firewood) use efficiency improvement and more efficient agricultural inputs use, leading to grain yield improvement. The alternative scenarios have significant positive environmental impacts in Sub-chain 1 and 2, while improvements in terms of environmental impacts are negligible in the case of Sub-chain 3.

Concluding remarks

The economic, social and environmental analysis all show that the sorghum value chain is sustainable and has high potential for growth and transformation, including significant upscaling of downstream value addition. However, it is hampered by constraints such as low productivity of sorghum producers, hazards in traditional pito brewing along with significant adverse environmental impacts. These constraints can be addressed if the improvements explored in this study are implemented. The outcome will be to unleash the substantial untapped potential in the value chain, through growth which remains inclusive.

In Section 7.4, we specifically analysed the impact of the incidence of COVID-19 on the value chain. Our analysis shows that though incidence of the pandemic in the sorghum-growing areas has been very low, the value chain has been affected due to the impact of measures adopted by Government to limit the spread of the virus. For instance, this led to a steep decline demand for products from the breweries, resulting in reduced offtake of sorghum grain by the industrial brewery. In the short-term there is likely to be a fall in total value added in the value chain due to shortfall in the contribution to value added at the level of industrial brewing. Contribution to public finance will also fall. Pito brewers are unlikely to experience much of a negative impact owing to the fact that most of their sales are at "spots" which are open and allow for social distancing. Value added by farmers is unlikely to be affected as the industrial brewery remains committed to take up the volumes contracted for. However, as payments to farmers has been delayed as a result of this situation, there is emerging evidence that it will negatively affect uptake of inputs by SHF2 farmers, resulting potential negative effects beyond the current season. Though incidence of the pandemic in rural areas is low, COVID-19 has shown the need for increased investment in rural health facilities in order to ensure preparedness to respond to similar outbreaks in future with higher levels of cases in rural areas. If that occurs, it is likely to have adverse effects on agricultural production, including sorghum grain output as happened in the case of the outbreak of Ebola in Liberia and other West African countries. In any case, such investment is needed to address the human health risks identified in the value chain (Section 3.4).

[3] *Only considering human diseases derived from environmental pollution linked to the life cycle of products or services.*

1 INTRODUCTION AND BACKGROUND

1.1 Background and objectives of study:

This Sorghum Value Chain Analysis is being undertaken in Ghana as part of a number of studies commissioned under the Value Chain for Development (VCA4D) Project funded by the European Union (EU) and implemented by Agrinatura[4]. The main objective of the VCA4D is to generate evidence, largely quantitative, and analytical information to underpin policy actions and interventions in the selected agricultural value chains. The studies involve the application of a common methodology to answer the following four (4) key questions:

a) What is the contribution of the target VCs to economic growth in the country?
b) Is growth in the VC inclusive?
c) Is the VC socially sustainable?
d) Is the VC environmentally sustainable?

The choice of value chains (VCs) to be studied is the prerogative of the European Union Delegation (EUD) in partnership with the government. In Ghana, the EUD selected the sorghum and groundnuts value chains, which are priorities for the Ministry of Food and Agriculture (MOFA), on behalf of the Government of Ghana (GOG). The overriding expectation of the EU (DEVCO) from the studies is a "snapshot" of the state of the VCs and to identify the main underlying factors responsible for the state of the VC. It also emerged from consultations with officials of MOFA that, in addition to this, the GOG expects the outcome of the study to include identifying potential areas where public sector actions can directly boost private investment in the sorghum value chain. The EUD in Accra also expects the outcome of the study to include practical interventions and recommendations which can improve prospects in the chain for various players, from smallholder farmers to relatively larger-scale investors.

1.2 Methodology:

1.2.1 Methods used

The team adopted mixed methods in undertaking the study. Data and evidence collection involved the use of various tools and resources including the following:

- Desk study involving review of literature, reports, relevant documents and online databases. Also reviewed are publications and reports (see references) on rural livelihoods studies, consumer surveys and some publications obtained from the Management team at the Market Oriented Agriculture Programme (MOAP).
- Interviews with key actors at all stages in the sorghum value, including experts and resource persons on themes related to specific components of the study i.e. social, economic and environmental issues. These interviews were either semi-structured or unstructured and centred around key issues in the value chain. See Appendix 1 for the list of interviewees.
- Surveys targeting key actors in the sorghum chain, including especially farmers and pito brewers. Structured questionnaires were prepared and used during the surveys as briefly reported in Section 1.3. (see Table 1.2).
- In addition, Focus Group Discussions (FGDs) were conducted targeting sorghum farmers (female and male) as reported in Table 1.1.

1.2.2 Analytical tools used

The team adopted mixed analytical tools including the following:

a) Basic statistical analysis to underpin the functional analysis;
b) Basic accounting framework for financial analysis of the operations of key actors;
c) Basic excel spreadsheets were used for the economic analysis including computing the total value added in the chain as well estimates of contributions to the national economy and assessment of the sustainability of the chain in the international economy;

[4] *Agrinatura is a grouping of European universities and research institutions involved in agricultural development in developing countries.*

d) Use of a standardised framework and scoring tool developed for the social analysis; and
e) Application of the Life Cycle Analysis (LCA) methodology and a proprietary software platform (SimaPro) in carrying out analysis of environmental sustainability and impact assessment.

1.2.3 Geographic focus of study

The geographic focus of the study is defined by the regions in which sorghum production and utilisation are concentrated. Sorghum production is concentrated in the five Northern Regions, which are shown in Figure 1.1 and consist of: Northern, Upper West, Upper East, North East and Savannah Regions. Consumption of the grain is similarly concentrated in these regions but its use for industrial brewing currently occurs mainly in the Ashanti Region, where Guinness Ghana Brewery Limited (GGBL) is located.

Figure 1-1: Map showing administrative regions of Ghana

Source: Ghana Statistical Services (Geographical Information Systems Section)

For reasons of logistics and time available for the missions, the team visited communities in the Northern Region (Tamale) and Upper West Region, mainly Wa (the capital) as well as towns and villages close to it. The team also visited Kumasi in the Ashanti Region to meet officials of GGBL and to consult farmers in the thriving pig industry in the region which uses spent grain from the brewery as well as experts at the Kwame Nkrumah University of Science and Technology. The Greater Accra Region was included in the field mission because Accra hosts head offices of several public agencies which were consulted. There are also a microbrewery, pito brewers and sorghum processors located in Accra and Tema.

1.3 Summary of activities undertaken:

1.3.1 The team

The study team consisted of the following:

- Gideon E. Onumah, NRI – Team Leader and economic expert;

- Christine Plaisier, WUR – Social expert ;
- Ricardo Villani, independent expert – Environmental expert; and
- Gregory Komlaga – National expert.

The team received valuable support from the EU Delegation in Accra (EUD), the Ministry of Food and Agriculture (MOFA) led by Mrs Angela Dannson of the Policy, Planning, Monitoring and Evaluation Division (PPMED), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in Accra and the Market Oriented Agriculture Programme (MOAP) team in Wa.

1.3.2 Stakeholder consultations

Pre-field mission activities included a briefing session in Brussels in April 2019, during which the team members went through the standard analytical tools developed for the VCA4D project and also discussed basic planning issues for the field missions. Two field missions were planned, the first taking place in May-June 2019 with the aim of achieving the following:

i) Get a full understanding of the sorghum VC in Ghana including the main actors, products, information and financial flows, and the institutional environment;
ii) Initiate functional analysis of the value chain;
iii) Identify sub-chains in the value chain and determine which of them will be the focal; and
iv) Initiate collection of data, information and evidence relevant for the three key analyses: economic, social and environmental.

The second mission took place in September-October 2019 and was used to fill any information gaps and to validate or enrich insights and preliminary conclusions outlined in the brief note submitted in June 2019. During the missions, the team conducted interviews with key informants representing various segments in the sorghum value chain. Some of the interviews were conducted by all the team members together whilst in some cases it was conducted by individual team members, depending on their specific areas of research (see Appendix 3 for the team's itinerary for the two field missions).

In addition, focus group discussions (FGD) were conducted with eight (8) groups of sorghum farmers numbering 132 farmers in total, and out of which 32% female farmers (Table 1.1 below). The FGDs were translated if necessary and guided by a set of prepared questions and topics of discussions. One of the FGDs was conducted during the first mission whilst the remaining seven took place during the second mission.

Table 1-1: Participants in focus group discussions organised during the Sorghum VCA study (2019)

Dates	Location	Male participants	Female participants	Total
May 24	Saboli	28	4	32
October 5	Mwofo Paala	9	3	12
October 5	Ul-Tuopare	10	3	13
October 5	Ping	12	0	12
October 5	Ping	2	2	4
October 6	Nyoli	12	3	15
October 6	Gindabou	0	12	12
October 6	Kpongiri	17	15	32
	Total	**90**	**42**	**132**

Source: Authors

Source: Authors (October 2019).

Figure 1-2: Focus group discussion with sorghum producers in Upper West Region, Ghana

The teams also conducted surveys during the second mission, with the aim of obtaining more detailed information than was obtained during the initial consultations with the main target respondents. The surveys were undertaken by three groups of local enumerators on behalf of the team. The surveys targeting farmers were conducted in farming communities near Tamale and Wa. The surveys in Accra and Tema mainly targeted pito brewers and sorghum grain processors. A total of 94 respondents were interviewed during the surveys (Table 1.2). They used a standard survey instruments jointly prepared by the team of experts but instruments were adjusted for each category. The categories targeted were: extension personnel in the field, sorghum farmers (smallholder farmers, commercial farmers and lead farmers), aggregators, traders, wholesalers and pito brewers (see Appendix 1.1 for the survey questionnaires). All data was entered into Excel templates and submitted to the research team in October 2019. The survey covered the following sections:

Section 1: Personal characteristics
Section 2: Farm/business practices and operations
Section 3: Operating costs and margins
Section 4: Regulatory issues
Section 5: Financing issues
Section 6: Food and nutrition security
Section 7: Housing

Section 8: Water and sanitation
Section 9: Health care
Section 9: Enabling environment and issues
Section 10: Other issues and recommendations

Table 1-2: Respondents interviewed in surveys conducted during the Sorghum VCA study

Category	Locations (towns/cities)				Total
	Tamale	Wa	Accra	Tema	
Extension staff	5	3			8
Farmers smallholder farmers	10	12			22
Commercial farmers	2	2			4
Farmers lead	3	3			6
Aggregators		2			2
Wholesalers	5	3			8
Traders	10	3			10
Pito brewers	10	11	7	6	34
Total	**45**	**39**	**7**	**6**	**94**

Source: Survey for Sorghum Value Chain Study (October 2019).

1.3.3 Defining key boundaries for analysis

In defining the scope for analysis in the sorghum value chain, the team took into account the following considerations: the cut-off date for analysis, especially as it impacts on the price and output data used as well as the key sub-chains and the actors operating in them. The focus of the analysis is also on the value chain which falls completely within national borders.

The cut-off year for analysis adopted by the team is 2018. This is in particular because GGBL reported offtake of significant volumes of sorghum grain – 18,000 tonnes. Consultations with their officials indicate that this figure is projected to rise within the medium-term (i.e. over the next five years), potentially reaching between 35,000 and 40,000 tonnes per annum. This will ensure that the full requirements of their brewery in Kumasi are met as well as supply to their plant in Accra, which is yet to use sorghum in their operations.

The projected increase in sorghum grain demand does not include potential offtake by the Accra Brewery Ltd. and other large-scale food processing enterprises. The main caveat is the year for the reported sorghum output used in the analysis. Though the figure is contained in an official report published in 2018, it is for 2017. We do not anticipate major variance for 2018 but can make adjustments if needed.

The study covers all the main actors and sub-chains in the value chain. However, the team notes that there are peculiarities in sub-chains which have significant economic, social and environmental implications. We identify three main sub-chains, which are discussed in more depth in Section 3.1 and illustrated in Figure 3.1. The identified sub-chains are:

a) **Sub-chain 1:** Sorghum grain production. This sub-chain is dominated by smallholder farmers who generally use very little or no yield-enhancing inputs (e.g. improved seed, fertiliser and pesticides). For purposes of this study we designate these farmers as **SHF1**. Consumption of sorghum grain by SHF1 households is quite important, though relatively larger volumes of rice and maize are reportedly consumed by these households, making the crop important in terms of household food security. The SHF1 producers also supply to artisanal *pito* brewers in rural areas and to the informal urban grain markets, through rural grain collectors as well as small/medium-scale aggregators.
b) **Sub-chain 2:** Smallholder farmers again dominate production in this sub-chain but they receive support from large-scale aggregators or commercial farmers to cover 20% of their inputs needs for sorghum cultivation. Part of their supplies of these farmers, designated by the team as **SHF2**, goes to the industrial brewery, through the supporting aggregators and commercial farmers. They also sell into urban food markets as well as pito brewers, microbrewery and sorghum grain processors. This portion of their output is sold through small/medium-scale aggregators. Household consumption also represents an important proportion of sorghum output by the SHF2. The emergence of the industrial brewery as a major sorghum

grain offtaker is influencing this sub-chain. Other actors who are important in this sub-chain include inputs suppliers, agriculture extension staff, transporters, grain wholesalers and retailers.

c) **Sub-chain 3:** This sub-chain has emerged principally because of entry by the industrial brewery into the market as an offtaker using sorghum grain for industrial brewing of beer and other non-alcoholic beverages from a blend of sorghum and imported barley malt. In addition to SHF2, lead (or nucleus) farmers, medium-scale farmers and commercial farmers are involved in producing sorghum grain the industrial brewery. Large-scale aggregators are key players in the sub-chain as are inputs suppliers, agriculture extension personnel, financial institutions, transporters and storage services providers. Though the volume of sorghum grain currently utilized in this sub-chain is rather low (representing only about 6.5% of total sorghum output), its potential to drive growth and transformation of the value is apparent. It is for that reason that attention is paid to Sub-chain 3 in the analysis.

The team used applicable generic industry-wide data in carrying out economic/financial analysis of the operations of industrial brewery (in Chapter 4) and the same in the life cycle inventory (LCI) of the malting and brewing stages in industrial brewing under the environmental analysis (in Chapter 6). Hence, the data used is mainly from secondary and expert sources. In the case of the economic/financial analysis, it makes it possible to avoid the risk of potentially disclosing sensitive commercial information. It also makes it possible to analyse the sorghum-based brewing operation as a distinct activity though in practice it is integrated, making it difficult for specific data to be obtained. The main advantage in using secondary LCI data is that it provides an opportunity to not only surmount data access challenges but also to generate a scenario that is applicable to any player interested in analysing the environmental implications of a shift from barley malt brewing to brewing with sorghum grains.

1.3.4 Reporting

The team has had two debriefing sessions during which emerging evidence from the study has been discussed. The first was held at the MOFA head office in Accra on 4th June 2019 and involved representatives from MOFA and the EUD. The team was represented by the Team Leader and the National Expert. Following that we submitted a Brief Note to the PMU in June 2019. The second debriefing session was at the offices of the EUD in Accra on 11th October 2019. The full complement of the research team participated in this meeting. Present were representation from MOFA, the EUD and GIZ/MOAP.

Highlights of the evidence generated during the first mission, which were borne in mind during further data collection and analysis during the second mission, are summarised below:

Pre-harvest issues

- Limited access to quality/improved seed contributing to variable output and relatively low yields.
- Current yields estimated at 50-60% of attainable levels.
- SARI (Savanna Agricultural Research Institute) faces funding constraints in breeding and in producing foundation seed (only 1 dedicated breeder and not enough supporting technical staff plus budget for experimental plots).
- The Plant Protection and Regulatory Services Division (PPRSD) is constrained in certification process (evidence of imported seed not performing may indicate challenges in enforcement process).
- Certified seed production technically more challenging for sorghum than other cereals – limited production capacity also due to uncertain demand.
- Focus of developing improved seed is mainly on white varieties for the breweries and this can lead to marginalisation of red varieties for pito and food.
- Finance a major constraint in accessing inputs even under Planting for Food and Jobs (PFJ) due to resource constraints facing aggregators who finance inputs procurement, with repayment in kind.
- Provision of extension services by MOFA staff under the Directorate of Agricultural Extension Services (DAES), complemented by personnel of the Nation Builders Corps (NABCO) as well as field officers of aggregators and of projects e.g. MOAP. Ratio of extension personnel to farmers remains low.
- Packaging of extension information – e.g. as under Modernising Agriculture in Ghana (MAG) reportedly not working too well, though approach seeks to link extension and research agenda to generation of issues from farmers through field extension personnel. The situation is also complicated by administrative structures (decentralised control of regional and district agricultural development structures under Regional/District Administrations).
- Perceptions of high risk and unstructured output marketing restriction supply of finance to under-capitalised aggregators. This is further accentuated by an unstructured payments system which is highly risky and characterised by significant payment delays.

- Improvements in the identified areas need to be explored.

Postharvest issues

- Sorghum consumption and utilization:
    - Uncertainty about volumes used for food and for pito brewing.
    - Anecdotes suggest rising consumption of maize/millet instead of sorghum in TZ (*tuo zaafi)*; perception as cash crop among farmers (any nutrition implications?).
    - Brewers spent grain valuable in pig farming (also at small-scale level) and demand rising from other poultry and livestock producers – will it remain a valuable bi-product or waste management issue with rising use by breweries.
    - Official estimates of surplus substantial (25-30%) – if correct could be suppressing output/productivity growth.
- Pito brewing:
    - Important in terms of absorption and inclusiveness but hazardous (punishment which keeps men out) – technology transfer to be explored which also have environmental implications.
    - Specialised malting emerging – can improve quality assurance.

Other issues

- Storage and aggregation facilities:
    - o Evidence of limited access but exploring improvements via the 1D1W will include how such facilities enhance structured marketing plus associated easing of access to production and postharvest finance.
    - o Transport facilities to be explored.
- Enabling policy and regulatory enforcement and implications to be explored including:
    - o Sustainable Research & Development: mechanisation, processing capacity etc.

1.3.5 Remaining activities and data limitations

The main outstanding activity is organisation of a stakeholder dissemination workshop to discuss the team's findings and any forward actions/recommendations which emerge. This is planned to take place after this report has been approved by the EU and is most likely to occur at the beginning of 2021. It is also anticipated that the EU will share and discuss the final report with MOFA and GIZ.

In terms of access to data and information for analysis there remain a few gaps. For the economic analysis, though the key data required has been obtained, it has not been possible to collect data on operational costs and margins related to commercial brewing of beer or production of other non-alcoholic beverages by breweries. It is unlikely that this information will be made available. We have therefore used the best possible estimates based on industry-wide projections for not only Ghana but also elsewhere. A similar approach was adopted in estimates used in the environmental analysis of industrial brewing using sorghum.

There are also a few data/information limitations to the social component, which were expected to be managed by the national expert. This includes data and information on the following issues:

- Working conditions: no direct information on wages, working conditions and satisfaction from the HR-department or from the workforce of the breweries.

Land and Water rights: information on the national land policies and VGGT adherence from the Land Commission in Accra.1.3.6 Structure of rest of report

Despite the challenges identified above, the team is confident that we have sufficient basis for analysis of the key developments in the sorghum value chain in Ghana as contained in the rest of this report, which is structured as follows:

- Chapter 2 presents an overview of the sorghum subsector, including production and utilisation of the crop at the global level and in Ghana.
- Chapter 3 focuses on a functional analysis of the value chain, including delineating the three sub-chains and describing the functions of the key actors, the typology of challenges and constraints they face and the main governance systems which exist in the main sub-chains.
- Chapter 4 covers the economic analysis including financial analysis of the operations of the key actors as well as estimates of the contribution of the chain to the national economy, employment generation, public finances and foreign exchange generation. Also discussed are issues on inclusiveness in the chain and viability in the international economy.
- Chapter 5 focuses on reporting on the social analysis, which goes beyond looking at the key actors as happens under economic and environmental analysis and addresses the issue of social sustainability from the perspective of six basic domains: working conditions, land and water rights, gender and social inclusion, food and nutrition, social capital, and living conditions.
- In Chapter 6 the results of the environmental analysis are reported and discussed, highlighting the key issues impacting on the environmental sustainability of the value chain.
- In Chapter 7 various options which can potentially transform the sorghum value chain in Ghana are explored. The outcome of our analysis of the impact of the COVID-19 pandemic on the sorghum value chain is also reported in this chapter.
- In Chapter 8 the main conclusions from the study are summarised along with recommendations which can improve prospects for inclusive growth and development in the sorghum value chain. The latter is done in response to the specific demand which emerged, especially from the EUD and MOFA, during the debriefing sessions.

2 OVERVIEW OF THE SORGHUM VALUE CHAIN IN GHANA

2.1 Strategic importance of agriculture in Ghana

Agriculture remains important in Ghana's economy, though its contribution to Gross Domestic Product (GDP) has been declining since the 1990s. In 1990 the share of agriculture in Ghana's GDP stood at 45% compared with 41% for services and only 14% for industry. By 2013 the sector had been overtaken by industry, the contribution from which had risen to 37% whilst that of agriculture had fallen to 22%. This was partly due to the emergence of the oil and gas industry. Official estimates by the Ghana Statistical Service (GSS)[5] reported that the contribution of agriculture to GDP in 2018 stood at 19.7% compared to 34% from industry and 46.3% from services.

The sector generates significant foreign exchange inflows. For instance, in 2018, cocoa exports accounted for just over 14% of the value of merchandise exports from Ghana, overtaken only by oil exports (30.7%) and gold (36.7%)[6]. It still tops the other sectors in terms of employment generation. In 2017 about 45% of the labour force was employed in agriculture, whilst services employed 41% and industry only 14% of the labour force. Most of the rural population are dependent on agriculture for their livelihoods.

Expansion of industry and services sectors partly explain why the share of agriculture in Ghana's economy has been declining. Another important contributory factor is the generally slower rate of growth in the sector compared to the others. Over the 5-year period between 2014 and 2018, the sector grew by an average annual rate of 3.4% compared to overall average GDP growth rate of 4.6%. The industrial sector grew by an impressive annual average rate of 6.6% over the period. It is projected that the agriculture sector will grow by 7.3% in 2019 as part of Government's plans to achieve overall GDP growth target 7.4% for 2019[7]. Achieving and sustaining this relatively ambitious sector growth target requires agricultural transformation, which is defined by Jayne and Ameyaw (2016[8]) as entailing a change from subsistence farming to commercialized, more productive agriculture accompanied by increased productivity, rising farm household income as well as growth in rural non-farm economic activities and job creation. The expectation is that this will produce highly positive impacts because, as noted by Thirtle et al. (2003)[9], a 1% rise in agricultural productivity empirically translates into a 0.72% reduction in poverty.

Agricultural transformation can potentially be achieved in Ghana because the country has substantial uncultivated arable land; its irrigation potential is under-exploited; and there exists a huge yield gap which can be bridged through uptake of available yield-enhancing technology. Furthermore, uptake of available postharvest technologies can increase food availability, even without increased output.

The rest of this chapter includes an overview of global production and utilisation of sorghum; followed by a brief discussion of conditions in Northern Ghana, where production of the crop is concentrated in the country. Utilisation of the crop in Ghana is also discussed as well as a review of the performance of the subsector, especially over the past decade.

2.2 Global sorghum production and utilisation

Sorghum – important in Northern Ghana (Section 2.3). This subsection overview of global production and utilisation – starting with its biology (why it is suitable for cultivation in the Northern Regions of Ghana).

2.2.1 The biology of sorghum

Sorghum is a warm short cycle annual, adapted to withstand higher average temperatures than most other cereal crops (Hall 2000). The best time to plant is when there is sufficient water in the soil and the soil temperature is 15

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[5] *GSS (2019) "Rebased 2013-2018 Annual Gross Domestic Product (Ghana)", April 2019.*
[6] *Bank of Ghana Annual Report 2018.*
[7] *Source: https://www.worldbank.org/en/country/ghana/overview*
[8] *Jayne and Ameyaw (2016) "Africa's emerging agricultural transformation: evidence, opportunities and challenges", Chapter 1 in Africa Agriculture Status Report, 2016. Report by AGRA, 2016.*
[9] *Thirtle, C., Piesse, J. & Lin, L. (2003). The Impact of research-led agricultural productivity growth on poverty reduction in Africa, Asia and Latin America. World Development, 31(12), 1959–1975.*

°C or higher at a depth of 10 cm. The minimum temperature for germination varies from 7 to 10 °C. At a temperature of 15°C, 80 % of seeds germinate within 10 to 12 days. Temperature plays an important role in growth and development after germination. Average temperatures between 24°C to 27°C after germination are ideal for best yields. Low temperatures can be limiting to sorghum growth (Carter et al. 1989) nd most plants will die when exposed to below freezing temperatures (Du Plessis et al. 2003). Exceptionally high temperatures cause a decrease in yield. Flower initiation and the development of flower primordia are delayed with increased day and night temperatures.

Sorghum is often grown in regions that get between 350–700 mm of precipitation annually (Fawusi et al. 1980). As a predominantly rain-fed crop, its yield depends largely on its drought resistance. The ideal soil moisture during germination ranges between 25% and 50% of field capacity and the sorghum plant can survive flooding events as it is more tolerant of wet soils (Fawusi et al. 1980 *ibid*). Sorghum is mainly grown on low-potential, shallow soils with a high clay content, which usually are not suitable for the production of maize. Sorghum usually grows poorly on sandy soils, except where heavy textured subsoil is present. Sorghum is more tolerant of alkaline salts than other grain crops and can therefore be cultivated successfully on soils with a pH (KCl) between 5.5 and 8.5. Sorghum can better tolerate short periods of waterlogging compared to maize. Soils with a clay percentage of between 10 and 30 % are optimal for sorghum production.

Grain sorghum is physiologically mature when moisture content drops to about 30%. At moistures higher than 25%, however, the seeds are too soft to withstand adequate threshing action, leading to either unthreshed heads or cracked seeds. Field drying to moisture level of about 12% makes the grain safe for storage. However, it may be preferable to harvest when the moisture content of the grain is between 20% and 25%. This is often done to minimise the risk of shatter loss but requires mechanical drying. Early harvesting may also be advisable in order to reduce the risk of lodging from wind and rainstorms as well as mouldiness which can be triggered by late rains during the harvest season.

2.2.2 Global production of sorghum

Sorghum is grown all over the world. Africa, North America and Asia are the top sorghum producing regions (see Table 1). In Asia, production is dominated by China and India, while in North America, the United States and Mexico are the top producers. In Africa, Nigeria and Sudan are leading producers of sorghum. In Sub-Saharan Africa, sorghum has significant presence in 38 countries. More than 90% of total global sorghum harvested areas are in Africa and Asia (Deb et al. 2004), with Africa accounting for 61% of the area and 41% of production and Asia accounting for 22% of the area and 18% of production. Over 61 million metric tons of sorghum were produced in 2013 with the top producers (in amount) being the United States, Nigeria, Mexico, India and Sudan. The majority of sorghum production was in Africa (41%), followed by the Americas (38%) and then Asia (18%) (Table 2.1).

Table 2-1: Global sorghum production per region (in millions of tonnes).

Region	2000	2005	2010	2013	2015
World	55.8	59.6	60.0	61.3	63.5
Africa	18.4	24.8	24.7	25.7	24.8
North America	18.0	15.7	15.9	16.4	17.2
South America	4.9	5.3	6.2	6.8	5.5
Asia	11.3	18.2	10.5	8.7	8.0
Europe	0.7	0.5	0.7	1.1	0.9
Oceania incl. Australia	2.1	2.0	1.6	2.2	2.1

Source: USDA: *World Agricultural Production*; Circular Series WAP 1-16

The United States of America (USA), Nigeria, Mexico, India, Sudan, Ethiopia and Argentina are the leading producers of sorghum. Total global production of sorghum in 2015 was estimated at 63.5 million tonnes, having risen by 13.8% over a 15 year period, from 55.8 million tonnes in 2000.

2.2.3 Risk factors in sorghum production

Sorghum remains below its yield potential globally. The reasons lie in its traditional reputation as a coarse grain used primarily as animal feed and dubbed ‘the poor man’s food’, reserved for low income populations (Mundia et al. 2019). Sorghum, unlike other cereals, is difficult to process into food-quality form. Although its nutrient composition does not largely differ from maize or wheat, brown sorghum has tannins that inhibit the assimilation of nutrients during digestion and the crop has general low digestibility.

Ten main factors have been identified to have notable impact on sorghum production within the major sorghum-producing regions globally. These are climate change, agricultural input, population/economic growth, biodiversity, agricultural resource scarcity, other crop demand, price, non-food demand, cultural influence and armed conflict (Mundia et al. 2019 *ibid*). These factors vary in their importance in different regions. Among all the factors, improved agricultural inputs, population and economic growth and climate change appear to be the most influential globally. Improved agricultural inputs increase sorghum productivity and can even lessen the negative effects of other factors. In the rural areas where subsistence sorghum is grown, population growth will mostly likely drive an increase in demand and therefore production, while for urban populations demand may decrease as food preferences change. Climate change is a threat, mostly to countries that rely on rain-fed farming and lack adequate adaptive capacity, for example via agricultural inputs. It is important to remember that localized factors such as culture and even conflict cannot be ignored when considering strategies to improve production in low yield areas.

Between the 1980s to the mid-2000s, sorghum production declined largely due to policy measures in Asia, North America and Europe affecting both supply and consumer preferences (Bhagavatula et al. 2013). Urban dwellers within the Sahel have begun to introduce more imported rice into their diets due to its affordability and fast cooking property, yet, in the rural areas, sorghum remains a substantial part of the diet (FAO 1995). Another major challenge is the infestation of the parasitic weed, striga, and bird and pest intrusion pre-harvest. Pest and disease control require greater agricultural inputs, such as herbicides or improved seed varieties, and since sorghum is mostly grown as a subsistence crop, this is not an affordable option. The effect of conflict plays a negligible role at a global scale, but in a selection of developing regions it is an occasional concern, and in the drier regions central to sorghum production its effects can be devastating.

2.2.4 Global sorghum utilisation

Starch is a very important component of sorghum, credited for its supply of energy. African cereals including sorghum often contain no gluten-forming proteins (gluten-free), thus making them safe to be consumed by people suffering from coeliac disease, or those allergic and intolerant to wheat, rye and barley. Sorghum contains varying quantities of essential minerals such as potassium, phosphorus and magnesium. Non-tannin phenolics, recognized for their high antioxidant activity were reported by to exist in significant amounts in sorghum grains.

Sorghum is mainly used as a feed for livestock in the United States of America. It is however consumed as food in most developing countries where it is milled into flour for preparing various forms of meals. Sorghum is used to brew a traditional drink, "pito", a traditional beer widely consumed in the Northern Regions of Ghana. According to FAO (1995), the brewery industry had exhibited interest in sorghum in the past years when investigations were made into its possible use as a substitute for barley malt in the production of lager beer. This would have been an earmark for industrial breweries to save foreign exchange. Even though research experiments proved successful, inadequate local sorghum varieties suitable to local conditions in terms of grain quality resulted in industries losing interest in the local sorghum production and many others abandoning the idea.

Sorghum is gluten-free grain. Ready-to-eat (RTE) sorghum-based breakfast cereal and other pastry products are potential markets for the crop. A gluten-free alternative to traditional wheat flaked biscuits has been long sought after, particularly by individuals with a wheat or gluten intolerance such as coeliac disease. Of additional value to sorghum's inherent gluten-free attribute would be any potential appetite and weight regulating functionality. Before testing for these potential effects in humans, it is important to confirm that the sorghum flaked cereal biscuits actually contain the implicated chemical and nutritional components and that processing has not negatively altered their physicochemical properties.

2.3 Sorghum production in Ghana

Sorghum is one of the main cereal crops produced in Ghana, ranked after only maize and paddy rice in terms of volume produced (Table 2.2). Production of sorghum in Ghana is dominated by smallholder farmers with land holdings dedicated to cultivation of the crop being two (2) hectares or less. Though most of the farmers use basic tools, such as cutlass and hoe, the use of tractor services and bullocks, especially for ploughing, is quite common in Northern Ghana. Inter-cropping and diversification of crop production are also quite common among sorghum and other food crop farmers. Monoculture in food crop farming is practiced mainly by large-scale or commercial farmers, who have only recently emerged in the sorghum value chain in response to demand by the industrial brewery. Based on the official data cited below in Table 2.2, the average yield obtained by sorghum farmers in Ghana is about 1.24 tonnes per hectare. However, data obtained during this study shows that average sorghum yield, especially what is obtained by smallholder farmers, is much lower, about 0.65 tonnes per hectare. This is reported and discussed in Section 2.3.5.

Table 2-2: Production of major cereal crops in Ghana (2017)

Crop	Area cultivated (hectares)	Total production (tonnes)
Maize	985,000	2,011,000
Rice (paddy)	241,000	721,000
Sorghum	224,000	278,000
Millet	156,000	163,000

Source: SRID, Ministry of Food and Agriculture (MOFA), 2017.

2.3.1 Agroecological conditions in sorghum-producing areas in Ghana

Sorghum production is concentrated in the Guinea Savana agroecological zone shown in Figure 2.1, which comprises the Northern, Upper West, Upper East, Savannah and North East Regions. Together these regions account for 97% of total sorghum production in the country[10]. The remaining 3% of sorghum output is shared between Brong Ahafo Region and the northern part of the Oti Region.

Figure 2-1: Agroecological zones in Ghana

Cultivation of sorghum in Ghana is largely rainfed. This is the case with most cereals produced in the country with the exception of rice, which is sometimes grown under irrigation especially in Northern Ghana. Unlike the southern parts of the country, the Northern Regions have a unimodal rainfall system, with the rainy season in May to October, compared to the bimodal system in the south from March to July and from September to October. The Northern Regions are significantly drier than the south of the country, receiving average annual rainfall of about 1,030 mm over the past 30 years. This is about 22% less than average annual rainfall in the south over the same time period. The only administrative region which is drier than the North is the Greater Accra Region with annual rainfall of about 790 mm.

The country is generally becoming drier. Official data indicates that average annual rainfall over the past decade (2008-2017) has been less than the 30-year average recorded by about 8%. The decline in volume of rainfall has been even more severe in the North, where the 30-year average annual rainfall stood at 1,030 mm but has fallen to about 875 mm. Hence, promoting the production of sorghum, a drought-tolerant crop, is an important climate-resilience strategy.

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[10] *Agriculture in Ghana – Facts and Figures (2017) Ministry of Food and Agriculture, Statistics, Research and Information Directorate (SRID), October 2018*

2.3.2 Socioeconomic conditions in the sorghum-producing areas in Ghana

Based on official data from MOFA, in 2016 the total area under sorghum cultivation in the Northern Regions accounted for 20.5% of cropped land, topped only by groundnuts with 23% share of cultivated land. Maize, rice, millet and cowpea are the other major crops cultivated in Northern Ghana.

The population in Northern Ghana is predominantly rural. According to the Ghana Living Standards Survey (GLSS of 2014), over 77% of the population in Northern Ghana lives in rural areas compared to a national average of 49%. Official statistics from the same source also estimate that about 90% of the rural population in Northern Ghana depends on agriculture for their livelihood. Even among the urban population in Northern Ghana, it is estimated that 43% depend on agriculture, in contrast with an average of only 22% for the rest of the country.

These statistics have poverty implications as poverty in Ghana is increasingly rural – about 38% of people in rural areas are deemed to be poor, compared to 10% in urban areas11. The incidence of poverty is especially high in agriculture-dependent communities, as the agriculture has generally recorded slower growth than other sectors in the economy12. According to the Ghana Poverty Mapping Report (2015) and an official report of the Special Rapporteur on Extreme Poverty and Human Rights on his mission to Ghana, the majority of persons living below the poverty live in the North13. The Ghana Living Standards Survey (GLSS of 2018) reports poverty incidence worsened in the Northern, Upper East and Upper West Regions over the intervening period between the surveys. A similar development occurred in the Volta Region.

2.3.3 Utilisation of sorghum in Ghana

The main uses of sorghum in Ghana are listed in Table 2.3. The bulk of the crop is used for food and for brewing the traditional beer – pito. Estimates on the volume used for these purposes range from 69% (FAO, MAFAP, 2013: 8) to about 90%14. Pito has low alcohol content and is often perceived as a food (energy drink). Obizoba (1988) reinforces this perception, noting that the process of malting seems to enhance the nutritional value of sorghum by increasing its total protein content and improving the quality of the nutrients. The traditional meals prepared with sorghum grains include the very popular tuo zaafi (TZ) and porridge. Milling of the grain into off-the-shelf flour for preparation of these meals is rather uncommon in most rural communities, where milling is done by the households at community-based hammer mills. This is the case even in urban areas.

However, as observed during this study, processing of sorghum grain into off-the-shelf products for preparation of porridge and as composite flour for confectionaries is burgeoning in urban areas in Ghana. Again this mirrors trends in other African countries. In Uganda, Tenywa et al. (2018) report that the market for sorghum-based processed food products is growing significantly, especially of products targeting children and adults with health issues. This is due to growing demand for gluten-free products in urban areas in Africa (Pontieri et al., 2013). Due to its high calorific and nutritional value health/nutrition experts in Nigeria recommend consumption of sorghum-based products by infants, pregnant and lactating mothers, the elderly and convalescents (Olbina, 2005).

Table 2-3: Sorghum utilisation in Ghana

Product	Description
Pito	Traditional alcoholic and non-alcoholic beverages
Food use	Household processing/preparation (e.g. TZ and porridge)
	Processed flour for preparation of TZ, porridge and other uses
Commercial brewery products	Beer and non-alcoholic beverages
Livestock and poultry feed	Spent grain – mainly for pig industry
	Feed grain
Other uses	Stalk and leaves for household use.

Source: Authors

[11] World Bank (2015), Poverty Reduction in Ghana: Progress and Challenges.

[12] Andy Mckay, Jukka Pritillä, & Finn Tarp, Ghana: Poverty Reduction over Thirty Years in "Growth and Poverty in Sub-Saharan Africa" (2016), 86-7.

[13] Philip Alston (Special Rapporteur on Extreme Poverty and Human Rights) on his mission to Ghana, 9-18 April 2018.

[14] Source: pers. comm. (Senior Research Fellow at SARI in May 2019).

Industrial uptake of sorghum in Africa has mainly been centred around its use in breweries as a substitute for imported malted barley as reported by Orr et al. (2016) for Eastern and Southern Africa, including specifically Uganda, where Nile Breweries Ltd (a leading brewery in Uganda has been promoting sorghum production for it since 2002 (by Tenywa et al. 2018). In Nigeria Heineken is reported to have been using sorghum in producing beer for the local market since 198915. Initial attempts made in Ghana in 2001-04 to promote contract-production for breweries recorded little success of difficulties farmers had in adopting new varieties (FAO, 2013). This was followed by an initiative in 2006-11 involving a Guinness-TechnoServe partnership. Uptake of sorghum by Guinness has gained significant traction since the emergence of a supply chain anchored around aggregators who are contracted by the brewery. In 2018, over 18,000 tonnes of sorghum were procured for the brewery through this process. Smallholder farmers dominate at production and this initiative has been successful due to adoption of varieties preferred by the brewery but not by traditional pito brewers.

Spent grain – an industrial "waste" from brewing beer or pito using sorghum – has a long tradition of being used to feed especially pigs. GGBL began selling the spent grain to pig farmers around Kumasi following successful trials in the 1980s by the Faculty of Agriculture in the Kwame Nkrumah University of Science and Technology. Pito brewers consulted during the study also confirmed supply of their spent grain mainly to pig farmers. The technical potential for sorghum leaves to be used as fodder for livestock and the stalks for fencing, staking, roofing, weaving baskets and mats as well as for fuel has been identified. However, in the course of this study, we did not find evidence to confirm such uses in the sorghum-producing communities visited.

The rather thin formal market for the crop – for processing and/or export – sorghum has not been perceived as a cash crop in Ghana (FAO 2013). Its role as an important food security crop, especially in the northern regions of Ghana, was not only due to its prominence in the food systems but also its resilience in terms of drought tolerance. However, there has been significant shift in Northern Ghana to the production and consumption of white maize. The successful introduction of early maturing maize varieties and the relatively larger market for maize grains were by stakeholders consulted as being among the factors driving this shift.

2.3.4 Overview of performance of sorghum sub-sector in Ghana

Figure 2.2 depicts sorghum production in Ghana, showing that over a period of three decades (1960 to 1990) output increased by just about 50%. However, sorghum production spiked in the 1990s, more than doubling in volume and peaking at over 387,000 tonnes in 1998. Since then growth in sorghum output has generally trended downwards, falling to 278,000 tonnes in 2018. Despite being grown on a very wide scale its performance, in terms of gross value of output produced per hectare, is rather dismal. Based on average farmgate prices in 2016, sorghum generated only an estimated GHC 1,300 per hectare of land, just about one-tenth of the value generated by groundnuts. Among the four crops listed in Table 2.2, sorghum out-performed only millet in terms of the value output produced per hectare.

Figure 2.3 shows trends in growth for the major cereals cultivated in the Northern Regions of Ghana over the period from 2008 to 2017. It shows that apart from the spike in 2017 and modest growth in 2008, growth in sorghum production has either been marginal or negative. It was generally been out-performed by all other cereals' subsectors except in 2017 when it was recovering after steep decline in 2016.

[15] *Source: https://www.borgenmagazine.com/sorghum-in-beer/*

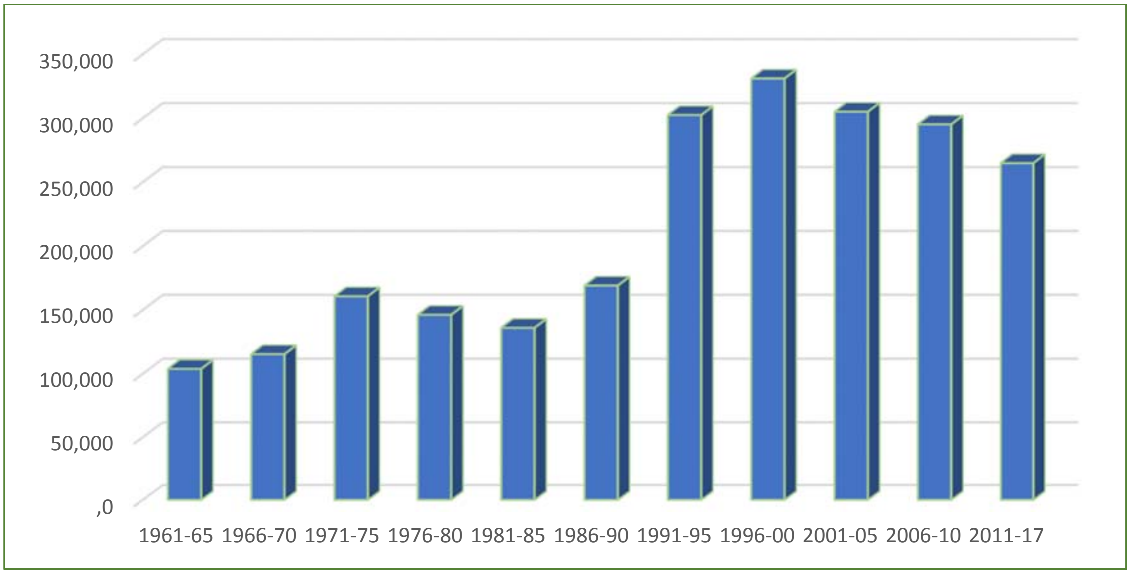


Figure 2-2: Sorghum production in Ghana (tonnes) 1961-2017

Source: Authors based on data from FAOTAT and SRID (2018)

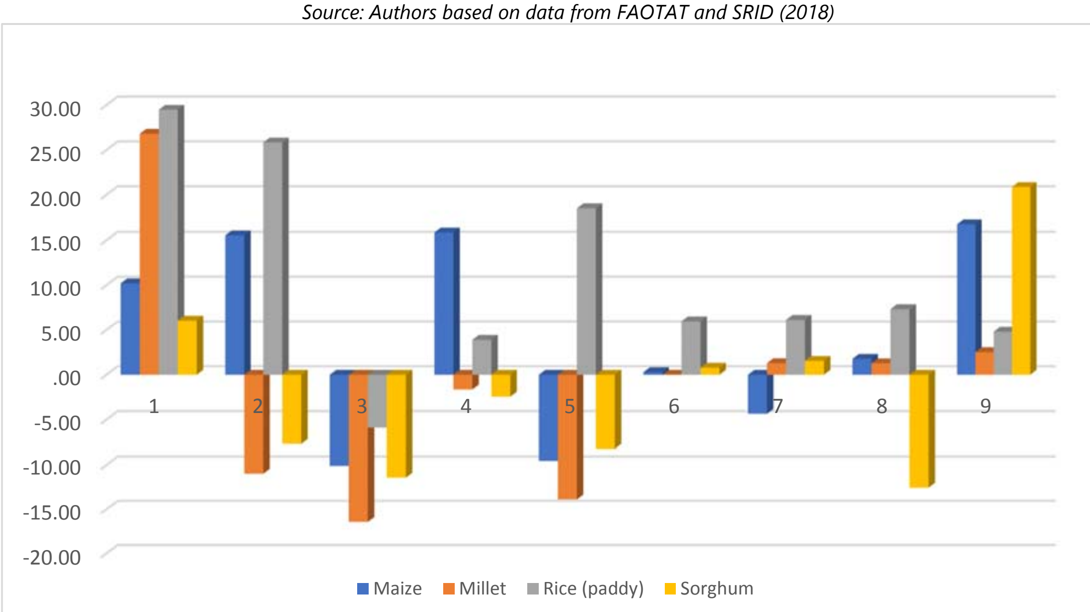


Figure 2-3: Annual growth rates for cereals in Ghana
Source: Authors based on data from SRID (2018)

2.3.5 Factors affecting sorghum production

Key among factors affecting the performance of the sorghum subsector in Ghana is the rather low average yield. Official data from Statistic Research and Information Directorate (SRID) estimates average yield for sorghum at 1.2 tonnes per hectare, which it projects to represent 60% of attainable yield of 2.0 tonnes per hectare. Other sources, however, estimate average sorghum yield in Ghana as varying from 0.5 tonnes per hectare to 1.0 tonnes per hectare. This is consistent with estimates from surveys of smallholder farmers in Northern and Upper West Regions, with the yield obtained by the farmers averaging about 0.65 tonnes per hectare.

We note that in the estimates by SRID, it is presumed that smallholder farmers are using improved seed and applying such as inputs fertiliser and pesticides at the recommended rates. This presumption is not consistent with responses from farmers consulted during the study, including the surveys. The farmers were unanimous in reporting that they did not use such inputs on their sorghum plots. In general, they cultivate indigenous, landrace[16] varieties with inherent low yield potential. They also scarcely apply fertilizer and plant densities tend to be low when they practice traditional mixed cropping systems. The average yield is substantially lower than what is obtained in Botswana (about 5 tonnes per hectare) and in Ethiopia and Uganda, where the average yield per hectare is about 2.0 tonnes (Orr et al. 2016). Evidence discussed in the next chapter shows that when farmers obtain inputs, even at lower levels through support from aggregators, the impact on yield is positive.

Natural risks to which sorghum production is vulnerable include the weather as well as pests and diseases. It is particularly prone to the impact of erratic rainfall, which as reported by farmers, is rising in incidence especially as late rains during the harvesting period trigger losses of volume of produce as well as its quality due to mouldiness. The latter particularly important to farmers producing for the industrial brewery market. Fall armyworm has been a challenge for farmers in the region over the past two seasons, whilst the most farmers consider birds as major pests. Some reported that the reason they plant sorghum close to homes, implying small plot sizes, is partly to ease bird control. The seed producers consulted cited yield loss due to birds as the biggest bottleneck in dry season production of seed, especially the relatively sweeter improved varieties preferred by the breweries.

Though it is considered a food security crop, domestic sorghum prices have consistently been higher than maize wholesale prices since 2008 as reported by SRID. In 2010 maize was about 25.4% cheaper than sorghum whilst in 2017 it was close to 35% cheaper. Ghana also appears to be a rather high-cost producer of sorghum. In 2017, when the wholesale price of sorghum was equivalent to about US$240 per tonne, global market prices ranged from US$100 to US$200 per tonne. In the Southern African markets the average price per tonne of sorghum during that year is reported to be over 30% lower at about US$160. Improving cost-competitiveness will require significant increase in farm productivity which is sustained by growth in demand for sorghum grain in market segments which offer prices which are not just high but also predictable.

[16] A landrace is a domesticated, locally adapted, traditional variety of a plant that has developed over time, through adaptation to its natural and cultural environment due to isolation from other populations of the species.

3 FUNCTIONAL ANALYSIS OF GHANA'S SORGHUM VALUE CHAIN

3.1 Introduction:

The main analysis in this study starts with the functional analysis, which defines the boundaries within which the range of actors and the functions they perform are examined. It entails mapping and describing the main actors, their activities and operations in the chain as well as an overview of the main products, production systems and product flows. This includes delineating the sub-chains and geographical regions the value chain analysis focuses on. The three main areas which this analysis consists of and are reported in this chapter are:

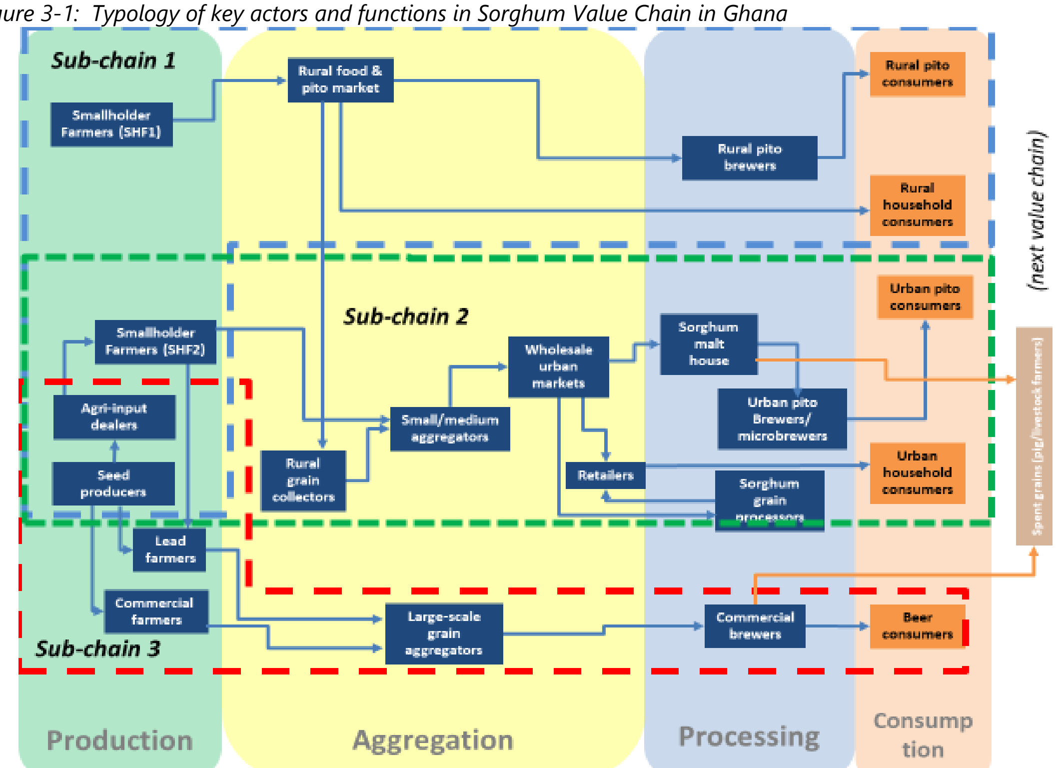
a. General description of the value chain system;
b. Technical diagnosis of the value chain; and
c. Analysis of value chain governance and coordination.

3.2 General description of sorghum value chain

3.2.1 Sub-chains in Ghana's sorghum value chain

The sorghum value chain consists of three sub-chains, a delineation which is based on the main end products supplied to consumers and is depicted in Figure 3.1. Sub-chain 1 consists of mainstream smallholder farmers (the SHF1), cultivating traditional low-yield varieties (landraces), mainly the red varieties. Use of sorghum grain produced in this sub-chain includes household consumption in the form of porridge or *tuo zaafi* (TZ), a traditional meal and is also brewed into pito which is consumed within the community. SHF1 farmers also sell to rural grain collectors in Sub-chain 2 for sale into urban markets for multiple purposes (detailed below).

Figure 3-1: Typology of key actors and functions in Sorghum Value Chain in Ghana



Source: Authors

Production in Sub-chain 2 is dominated by the emergent SHF2 farmers, who as noted in Section 1.3.3, receive support from large-scale aggregators and commercial farmers to acquire yield-enhancing inputs such as fertiliser and pesticides. The marketed surplus of sorghum grain produced by the SHF2 enters the market through two main channels, consisting of:

- ❖ Sub-chain 2: they sell directly to small/medium-scale aggregators who supply to wholesale markets in urban areas, bypassing the rural grain collectors because they sell in larger volumes and comparatively better quality grains due to their experience in trading in Sub-chain 3. In the urban informal market, the sorghum grain is sold to pito brewers as well as retailers who sell to household consumers as well as small-scale processors and microbrewers. Though in rural areas pito brewing tends to be combined with farming, it is a specialised activity in urban areas.
- ❖ Sub-chain 3 has only recently emerged and centres around the supply of sorghum grain to the industrial brewery. It involves facilitation of community-level aggregation by lead farmers who are paid a commission for delivery to large-scale aggregators to whom they are linked. The lead and other medium-scale farmers (LMF) also contribute a significant share of the sorghum grain supplied to the industrial brewery. In addition to their own production, the commercial farmers (CF) also aggregate from SHF2 farmers who are part of their outgrower schemes.

There is interest in this study on how Sub-chains 2 and 3 are evolving, partly because of the contribution to value addition as well as potential for inclusive growth in the medium to long-term. However, all segments of the entire value chain are analysed, including Sub-chain 1, which produces the bulk of sorghum grain in Ghana and also has peculiar challenges. Figure 3.2 shows the flow of sorghum grain through different distribution channels to various end-users. Table 3.1 shows the volumes of sorghum produced, marketed and consumed by each category of farm households.

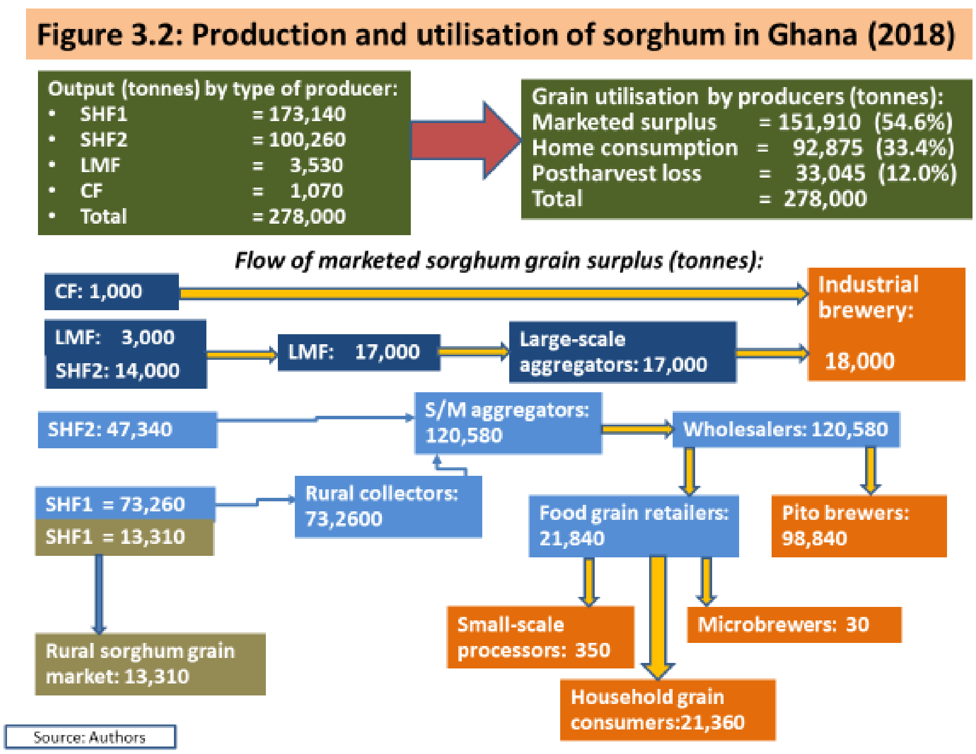


Figure 3-2: Production and utilization of sorghum in Ghana (2018)

Table 3-1: Sorghum production and marketing by different categories of farmers in Ghana (2018)

YIELD/PRODUCERS	SHF1	SHF2	LMF	CF	Total	Share (%)
Estimated number of producers	173,140	47,180	350	4	167,984	
Average area planted with sorghum per household (hectares)	1.53	2.5	5.6	100		
Total area planted with sorghum (hectares)	266,370	117,950	1,960	425	386,705	
Estimated yield per hectare (tonnes)	0.65	0.85	1.8	2.5	-	
Total output per category of farmers (tonnes) – of which:	173,140	100,260	3,530	1,070	278,000	100
- Volume of marketed surplus of sorghum grain (tonnes)	86,570	61,340	3,000	1,000	151,910	54.6
- Volume of sorghum consumed by household (tonnes)	65,790	26,890	175	20	92,875	33.4
- Estimated volume of postharvest loss (tonnes)	20,780	12,030	185	50	33,045	12.0
OTHER DETAILS:						
Contribution to total sorghum grain output (%)	62.3	36.1	1.2	0.4	100	
Contribution to marketed surplus of sorghum grain (%)	55.8	41.4	2.1	0.7	100	
Contribution to grain for pito, microbrewing & processing (%)	64.7	35.3	-	-	100	
Contribution to sorghum grain supplied to industrial brewer (%)	-	77.8	16.7	5.5	100	

Source: Authors

As shown in Table 3.1, about 33% of sorghum grain produced in Ghana is consumed at the household level by producers. We estimate per capita consumption of sorghum grain at household level at between 0.5 to 0.6 tonnes (10 to 12 bags of 50 kg) per household. The volume of sorghum grain which enters the marketing/distribution chain is close to 55%, with the remaining 12% representing losses which occur during harvest and at postharvest17. There is no indication that this volume of output – about 33,000 tonnes – is either consumed or sold and, for that reason, we do not take it into account in the economic analysis.

The distribution channel linking SHF2 farmers as well as LMFs and CFs to the industrial brewery is new and involves strict enforcement of grain quality standards, especially with regards to acceptable moisture and aflatoxin levels. Standard weights and measures are also applied. So far this market segment accounts for only 9.5% of the marketed sorghum grain but has the potential to grow as well as drive increased industrial utilisation of the crop, as discussed in Chapter 7. The larger market for sorghum, which involves both SFH1 and SHF2 farmers, is predominantly informal and does not involve enforcement of commodity standards.

3.3 Typology of actors in sorghum value chain

3.3.1 Sorghum grain producers in Ghana

Until recently, sorghum was produced mainly smallholder farmers, cultivating between 0.5 and 2.0 hectares per season (according to MOFA estimates). However, as shown below, a more diverse range of producers are emerging, due mainly to the formal sorghum grain procurement channel which is linked to the industrial brewery.

Mainstream smallholder sorghum producers (SHF 1)

Data from surveys conducted during this study, and summarised below in Table 3.2, shows that this category of smallholder farmers cultivate about 1.5 hectares of sorghum during the season. This represents only 30% of the total land area they cultivate. About 50% of the rest of the cultivated area is dedicated to maize production, whilst the remaining 20% is used in growing other crops such as rice, soya, groundnuts, cowpea and millet.

Table 3-2: Characteristics of small/medium-scale sorghum farmers in Northern Ghana

Category of farmers	Average area cultivated per farmer per season (Ha)	Area allocated to sorghum (%)	Area allocated to maize (%)	Area allocated to other crops (%)
Mainstream smallholder farmers – no inputs (SHF 1)	5.0	30	50	20
Emergent smallholder farmers (SHF 2)	6-7	40	25	35
Lead (medium-scale) farmers	9-10	60	22	18

Source: Farmers survey conducted in Northern and Upper West Regions (October 2019)

In general and, as confirmed through the survey, this group of smallholder farmers (SHF 1) plant low-yield sorghum landraces, mainly as retained planting material from grain produced during the previous season. There is no evidence that they use any form of fertiliser and pesticides nor is there any application of herbicides for weed control. From our survey and consultations with plant breeding experts at SARI, we estimate the average yield per hectare for the SHF 1 sorghum farmers at 0.65 tonne, which is significantly lower than the official estimate of 1.2 tonnes per hectare. They sell any marketable surplus to itinerant or community-based micro-scale aggregators who usually buy only a few kilos per farmer.

Emergent smallholder sorghum farmers (SHF 2)

Evidence from field observations, which was validated by the farmers' surveys, especially in the Upper West Region, shows that there is an emerging group of smallholder farmers who are taking advantage of the marketing chain linked to the breweries to scale up sorghum production along with the adoption of practices and technology which increases farm productivity. As shown in Table 3.2, the SHF 2 farmers, just as their counterparts above (SHF 1 farmers), cultivate a diverse range of crops. Their area cultivated is relatively larger, about 6-7 hectares in a season, and they also allocate much larger share of their land (about 40%) to the cultivation of sorghum. Only 25% of cultivated land is allocated to maize, whilst 15% is allocated to groundnuts and the remaining 20% for other crops.

[17] *Source: African Postharvest Losses Information System (APHLIS) – https://www.aphlis.net/en#/*

In addition to expanding the area they cultivate, the SHF 2 farmers utilise yield-enhancing inputs such as fertiliser, pesticides and improved seed (in particular the white sorghum varieties preferred by the breweries). A major factor driving their emergence is the new and growing formal sorghum grain market linked to the breweries. Reports available to officials of MOAP from Agriculture Extension Agents (AEAs) in, for example the Jirapa District in the Upper West Region, confirm that some smallholder farmers are shifting away from maize to sorghum production due to the availability of a ready market centred around aggregators who supply sorghum grain to the industrial brewery. The aggregators as well as some commercial sorghum farmers enable the SHF 2 farmers to access inputs through schemes such as the one described in Box 3.1 below.

Box 3.1: Emerging formal market for sorghum grain catalyses growth in smallholder productivity

Smallholder sorghum farmers in Northern Ghana are making transition from low-input, low-productivity to more productive producers who are also scaling up area under sorghum cultivation. This is evident in the growing number of smallholder farmers (described above as SHF 2 farmers) who are participating in sub-chain which supplies quality sorghum grain to breweries, specifically the white varieties. Participating farmers cite the offer of price premium for quality grains, adoption transparent weight systems in the trade (in contrast with the volume-based informal trade where "cheating" on weight and admixing is a common practice). Producers have an assured market in which output prices are expected to be fixed before harvest and can sell in bulk rather than in small volumes to the severely under-capitalised micro-scale aggregators.

Participating farmers are also assisted by aggregators to acquire inputs such as improved seed, fertiliser and pesticides as well as tractor services for ploughing. This support involves interlocking inputs credit with grain marketing. Farmers receive inputs on credit and repay by supplying pre-determined volumes of grain to the aggregators, who usually buy any surplus the farmers may have.

Funding for the inputs credit schemes is usually obtained by aggregators from project-related sources such as the MOAP-supported Inputs Revolving Fund in the Upper West Region and the Outgrower and Value Chain Fund (OVCF) in the Upper East. Aggregators can fund this activity with loans from commercial banks, which are secured against their balance sheets and other collateral such as real estate. However, this form of finance is very limited in agricultural value chains in Ghana. Due to limited funds, the inputs credit support is usually limited to requirements for cultivating one acre or 0.4 hectares per farmer.

Farmers benefit through rising yield per hectare but considering that only a fraction of the area cultivated is planted the overall increase in yield is estimated at 0.85 tonnes per hectare, which is about 30% higher than their SHF 1 counterparts. It is possible to close the overall yield gap – i.e. between this and the official estimate of attainable yield – if they receive support covering a larger area of the land they cultivate. Aggregators also benefit from being assured of supply of quality grains to fulfil obligations to industrial breweries.

Source: Authors.

Lead (nucleus)/medium-scale farmers[18]

Lead (or Nucleus) farmers play a central role in the newly emerging sorghum Sub-chain 3 as is illustrated in Figure 3.3 below. Their average farm size is similar to that of medium-scale farmers, for which reason we classify them together. However, in addition to selling sorghum grain which they cultivate, they also mobilise SHF 2 farmers in their communities into groups which they lead. The groups are linked to aggregators or commercial farmers who provide inputs support and guarantee a market for the sorghum grain produced. The team describes these farmers as Lead rather than the more common terminology of Nucleus farmers because unlike the typical nucleus farmers, they do not on their own provide inputs on credit or guarantee purchase of output from the participating SHF 2 farmers.

[18] *The description of these farmers as lead farmers is in order to distinguish them from Nucleus farmers, who in a technical sense may own large-scale farms or plantations and provide inputs and other services to outgrowers on credit and engage in downstream aggregation in order to recover inputs loans and to secure supplies for processing or trade.*

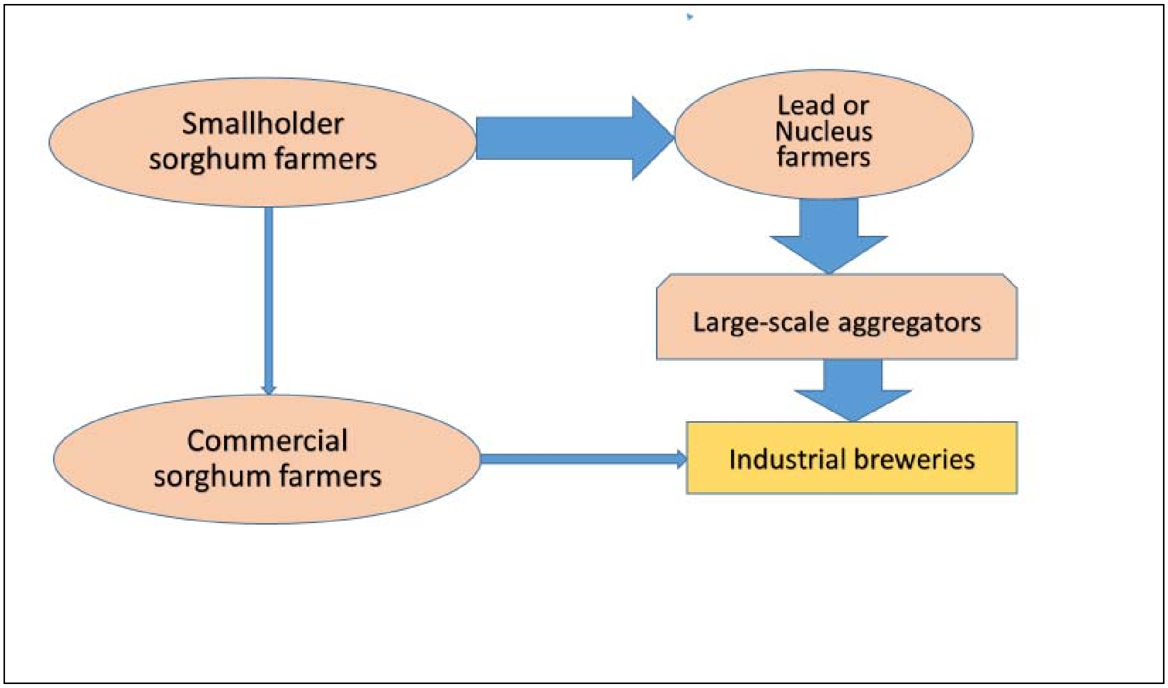


Figure 3-3: The Breweries-linked sorghum supply chain in Ghana

On the average this category of farmers cultivate about 8.5 hectares of land per season. Like other smallholders, they do not engage in mono-cropping but cultivate a range of crops. About 60% of the land area they cultivate goes to sorghum, another 22% to maize and the remaining 18% to other crops. The lead farmers are paid commissions by aggregators when they ensure delivery of output by the SHF 2 farmers, both for repaying inputs credit and any extra output the farmers have. They also receive support in the form of inputs credit from aggregators but usually have the means to acquire inputs for about two (2) hectares of sorghum, resulting in a significant increase in the yields they obtain per hectare, an average of 1.8 tonnes.

Commercial farmers

This category of farmers, on the average have, a minimum of about 30 hectares of land under sorghum cultivation in the Northern Regions of Ghana. In 2017, six (6) such farmers were under contract to supply sorghum grain to the industrial brewery but by the time of the study this number had been reduced to four (4). Apart from one case (Box 3.2), all the commercial farmers went into sorghum production after earlier supplying maize grain or grits to breweries under contract – an example is Mango City Ltd. (Box 3.3), which has a sorghum farm near Daboya (close to Tamale in the Northern Region). The atypical case, which is this new entrant (Box 3.2), who invested in sorghum cultivation in 2019, mainly because of potential access to the breweries market.

As illustrated in the two cases (Boxes 3.2 and 3.3), commercial farmers grow multiple crops, mainly cereals such as maize, soya, cowpeas and rice in addition to sorghum, their production of which involves outgrower schemes with smallholder farmers. Access to land does not appear to be a constraint – typically requiring an investor to demonstrate commitment to involve farmers in the community in addition to creating jobs, especially for the rural youth. Acquiring land does not require payment of specified sums but of *"goro"* (small amounts to show respect to the chiefs who release the land). The farmers are also required to pay annual "homage" in the form of produce given to the chiefs for use of the land – not fixed but as deemed "good" by the farmers.

Access to fertiliser and pesticides is also not a challenge to the commercial farmers, who can obtain their requirements in full under the PFJ and the government subsidised prices. The allocations of these inputs which they obtain include the requirements for the outgrower farmers. However, since they pre-finance purchases on behalf of outgrowers, with repayment in kind at harvest, they are generally able to cover supplies for only one (1) acre per outgrower smallholder farmer.

The commercial farmers have tractors which enable them mechanise land preparation, including ploughing and harrowing as well as using planters. They offer ploughing services to their outgrowers on credit – usually limited to about one (1) acre per smallholder farmer. Weed control involves use of herbicides as well as manual labour. Harvesting is manual due to lack combine harvesters, but threshing is mechanised, a service which they sometimes extend to the outgrowers.

Reliance on local labour, including from their outgrowers, for harvesting is one of the major challenges faced by the commercial farmers. Access to labour is a problem around the harvest season as outgrowers often complete harvesting from their own plots before working for others. Consequent delays in harvesting lead to significant losses, especially where late rains during the harvest result in mouldy crops which cannot be sold to breweries because of Aflatoxin contamination. This is cited in the case in Box 3.3 as one of the main reasons for scaling down direct production of sorghum by the company. They are rather scaling up production by outgrowers who can better manage harvesting because of the relatively smallholder holdings.

The commercial farmers also reported having difficulties accessing quality seed. In one particular case cited in Box 3.3, they were assisted in 2018 with the supply of seed imported from the USA. Though the imported variety did very well during gestation and head formation, they encountered huge losses due to quality problems resulting from substantial absorption of moisture close to the harvest season. The company discontinued planting that variety in 2019.

Box 3.2: New commercial sorghum producer in Upper West Region, Ghana

The company started sorghum production in 2019 but has experience in aggregating the grain for supply to traders in the Techiman Market in the Brong Ahafo Region, which is the largest grain market in the country. It is headed by a young female entrepreneur. In 2019 the company cultivated about 30 hectares of sorghum and supported over 120 smallholder outgrowers to cultivate another 175 hectares. In addition, they have 160 hectares under soya cultivation and outgrowers with 20 hectares planted with soya. Most of their outgrowers and local temporary labourers (by-day labourers) are women.

So far this commercial farmer has had no challenges in terms of accessing land or inputs distributed under PFJ. They acquired seed mainly from local markets though their preference will be from licensed seed suppliers or agro-dealers. They have three tractors, considered sufficient for their own operations though inadequate in meeting demand from their outgrowers. They have also benefited from advisory services from MOFA staff, including the Regional Director, as well as the experienced farmers among the outgrowers. They intend to supply their harvest directly to the industrial brewery because of an existing contract with the price fixed in October 2019. They encountered problems with fall armyworm but reported that it had been contained. They have no on-farm storage facilities.

Source: Authors based on field visit in October 2019.

In general, the commercial farmers are considered the most productive, achieving yields estimated at about 2.5 tonnes per hectare. This makes them preferred candidates as medium to long-term suppliers to the breweries, including being potentially more price competitive. However, they have concerns about the long-term sustainability of the supply chain linked to breweries, especially as some of them in the past invested in capacity to supply maize grits after which there was a switch to sorghum.

Box 3.3: Diversified commercial farmer engages in sorghum production in Northern Region, Ghana

The company has been operating since 2011 with its core focus being on the production and processing of mangoes for domestic and export markets. They intercropped mango with maize, cowpeas and also vegetables. They started operations in the Upper East Region but subsequently expanded to Daboya the Northern Region in 2016. During the 2017 season they planted 200 hectares with sorghum but had no outgrowers. In 2018, they scaled down their own production to about 120 hectares but engaged outgrowers planting about 80 hectares. This trend continued in the 2019 season with the company cultivating about 40 hectares of sorghum with outgrowers cultivating close to 250 hectares.

One of the main reasons they went into maize grain production was to supply the grain under contract to a processor supplying maize grits to the breweries. When one of the breweries switched to using sorghum grain, Mango City also got into production of the crop – motivated by the availability of a formal market.

In addition to providing inputs credit – covering requirements for one acre per farmer – the company also offers ploughing and threshing services. So far, the major challenges they have encountered are: access to quality sorghum seed, difficulty in securing labour for timely harvesting in order to avoid quality problems, especially when the rainy season extends late into the harvest. This is the main reason why they are scaling back on their own planting and relying more on supplies from outgrowers who are better able to cope with harvesting challenges by using family labour. They have on-farm warehouse, but it requires considerable remedial works in order to make it serviceable.

Source: Authors based on field visit in October 2019.

3.3.2 Typology of aggregators and traders in the sorghum value chain

The aggregation function is relevant in Sub-Chains 2 and 3 but not in Sub-chain 1, servicing the rural food and pito markets. The rather small volumes traded in Sub-chain 1 usually do not require the involvement of aggregators.

For Sub-chain 2 the frontline aggregators are ***rural-based collectors*** buying a few kilograms up to about one (50kg bag) at a time, the main factor limiting their scale of operation being the fact that they are severely under-capitalised and have no access to credit. They trade on cash basis and don't benefit from any trade credit even though they are domiciled in the same communities as the farmers. They usually sell to medium-scale aggregators with whom they have long-term relationship.

The ***medium-scale aggregators*** tend to bulk up to a truckload – about 7.5 tonnes of produce per trip, which is delivered either to traders in wholesale markets in urban areas or to the large-scale aggregators supplying to the industrial brewery. In general, they generate working capital from own resources and/or from relatives. A few of them may have benefited from credit obtained from microfinance institutions, rotating savings groups and sometimes from rural/community banks.

Large-scale aggregators have only emerged recently in the sorghum value chain and are mainly visible in Sub-chain 3. One of the most notable examples is Agriaccess which is based in Wa in the Upper West Region (and described in Box 3.4). Other aggregators in Wa include Antika Ltd, which in addition to grain aggregation is also engaged in the supply of inputs and tractor services to farmers. Antika Ltd. is more diversified in terms of commodity trade and is particularly active in marketing groundnuts to processors in Accra/Tema. These aggregators have proved crucial in the development of Sub-chain 3 of the sorghum value, ensuring inclusiveness in the form of participation by smallholder producers. This is because they assure delivery of quality grains to end-users such as the breweries and ease access to inputs by smallholder producers.

Box 3.4: Sorghum aggregator in Upper West Region, Ghana

The company is one of the leading suppliers of sorghum grain to the industrial brewery, currently supplying over 3,000 tonnes per year. It used to cultivate about 10-12 hectares of sorghum but currently relies entirely on production from a network of over 3,200 SHF 2 farmers. It pre-finances acquisition of inputs and ploughing services for its farmers with repayment in the form of sorghum grain delivered through Lead Farmers.

It has a quality assurance system based on quality standards set by the breweries and their farmers are trained to comply with the set standards. The company reported less than 1% rejection of the stocks they delivered over a period of more than five years. The deliveries by the farmers are through small-size rural aggregation facilities built by different donors and with storage capacity of 50 tonnes or less. These are equipped with scales, ensuring that farmers are paid per kilogram supplied rather than on volume basis.

The price and margins for aggregators and their farmers are negotiated with the industrial brewery every year based on the crop budgets they submit. Farmers' involvement in this process is rather marginal. The price is expected to be set before planting but was disseminated rather late in 2019 – around late October. The company accesses working capital as well as financing for inputs and services for farmers from a mainstream commercial bank. They have recently constructed a warehouse with storage capacity of 1,000 tonnes with modern cleaning equipment and onsite grain laboratory with capacity to carry out aflatoxin tests.

Source: Authors based on field visit in October 2019.

Figure 3-4: Grain retailer in Tamale market, Ghana
Source: Authors (May 2019)

Sorghum traders in urban markets
Retail trade in sorghum, especially in urban markets, is dominated by women who generally specialise in selling a range of cereals as opposed to particular crops (Figure 3.4). Most of the retailers enter it by first assisting their mothers. They take over when the mothers "retire" or when they move to new areas with their spouses. They obtain their supplies from "wholesalers" who sell 1-2 bags to them – sometimes on credit but requiring repayment when stock has been sold.

3.3.3 Typology of end-users of sorghum grain

In Ghana, the main processed products from the sorghum value chain are alcoholic/non-alcoholic beverages – the traditional pito and beer and non-alcoholic malted drinks; as well as processed flour for preparation of various foods at that household level and for confectionaries.

Formal brewers
The main processors include commercial breweries, who are driving the development of Sub-chain 3. They use sorghum for both alcoholic beer and non-alcoholic beverages (Figure 3. 5). As reported, they currently utilise about 18,000 tonnes of sorghum grain in their plant in Kumasi. This is expected to rise to between 35,000 to 40,000 tonnes per annum when they expand the product lines using sorghum as well as use the grain for brewing in their plant in Accra. Operating in a highly competitive market which is also tightly regulated by the standards authorities, the brewery strictly enforces quality standards pertaining to their raw materials. They are particularly stringent in ensuring compliance with maximum Aflatoxin levels and also in the type of sorghum varieties they use as it affects product quality and milling efficiency of the malted sorghum grains.

GGBL products in Ghana

Source: Africa.Businesschief.com

Figure 3-5: GGBL products in Ghana

There is potential for Accra Brewery to take up sorghum though this has been difficult to establish at this stage in the study. There are also indications that a major international beer brand will permit use of sorghum in brewing its product under licence if the quality of the grain is assured. Investigations into this had started during the second mission of this study, involving evaluation of aggregation and storage facilities for sorghum in the Upper West Region.

Figure 3.6: producing 100% sorghum beer with customised labels

Source: Authors

Figure 3-6: Producing 100% sorghum beer with customized labels

Microbreweries which can use sorghum for brewing various products, are also emerging in the country (Figure 3.6). These are micro/small-scale breweries requiring investment of the scale of about US$500,000 and employing 4-5 staff. They produce on contract or for supply to specific outlets or individuals, sometimes with customised labels. There is currently only one such brewery in operation though there is evidence of interest to invest in this by other entrepreneurs. They tend to source sorghum grain from the main informal markets in Accra and not from the formal distribution channel which has emerged around the industrial brewery.

As they are not marketing specific branded products, they are not subject to the same level of stringent regulatory control as the main breweries. However, their main customers appear to be discerning middle-class consumers in urban areas, they need to ensure quality products. The main challenges militating against scaling up this activity includes limited access to required equity as well as working capital. In addition, regulatory enforcement is likely to strengthened, implying greater investment in facilities which comply with existing product quality as well as process standards. These issues are explored further in Chapter 7.

Pito brewers
Though pito brewing absorbs the bulk of sorghum produced in the country, it remains an artisanal activity in both rural and urban areas. The process is pretty artisanal – using basic malting and brewing technology, involving open-fire boiling of the malted, milled sorghum. It is dominated by women who often learn from and/or take over the operation from their mothers. As evident from Figure 3.7, the process involves a number of hazards, including smoke from using open-fires and the risk of snakes and scorpions hiding in piles of the firewood (there was one such incident during a visit by the team in the course of the second mission).

Equity for investment in pito brewing does not appear to be a significant barrier. This is largely because brewers takeover businesses from mothers or accumulate required capital through "working" as assistants to other brewers. The margins from pito brewing, especially in urban communities, as analysed in the next chapter, are sufficiently high enough to maintain households. However, men are yet to be motivated by this incentive to compete with women in pito brewing – generally perceived as a "woman's business". Technology upgrades are likely to reduce the hazards associated with pito brewing and some of the innovations are discussed in Chapter 7. In that discussion, we briefly review of the implications of such upgrades on the existing gender configuration in pito brewing.

Figure 3-7: Pito brewery in Wa, Upper West Region, Ghana, May 2019.
Source: Authors

Sorghum flour processors
Processing of sorghum into flour for home cooking (mainly for porridge) as well as for baking bread and other confectionary products is growing in urban areas but mainly on a micro-scale. The processors tend to process and package a range of cereals including sorghum, maize, millet, soya and nuts. Some are packaged as composite flours e.g. maize/millet/sorghum as health foods whilst the confectionary products substitute for wheat, targeting the emerging market in urban areas for gluten-free products.

As is the case with the microbrewery, they tend to source their grains from open markets in urban areas, including e.g. a popular market in Nima (suburb of Accra). There are others who also obtain their supplies in the form of grain or already milled flour from friends/relations in the Northern regions. Milling is often done using community-based non-dedicated mills. They may have 1-4 staff who sort the grains before milling and package the milled product. Distribution of the products is through either their proprietary shops or to retailers they know very well. Indeed, one of them already has an agreement with a major fuel marketing company to distribute some of their products but so far not sorghum flour.

The processors consulted have higher education qualifications (secondary level and beyond) and some have had experience working in the formal sector. Entry into this activity is often motivated by the need for supplementary income. Considering that they usually start from facilities at their homes, start-up capital is not a significant constraint. Furthermore, at the micro-scale, lack of working capital is not considered as a critical constraint.

What has emerged as the most critical barrier to the upscaling of the operations of this category of actors is their capacity to comply with regulatory requirements for licensing their products, which will allow them access to formal markets such as supermarkets. All the companies consulted are properly registered but products remain unlicensed. This is not only because of the high cost of licensing the products but more so because of the stringent food safety and other formal processing standards they need to comply with. This is an issue which we discuss further Section 3.4 and also in Chapter 7.

3.3.4 Typology of service providers in sorghum value chain

Most of the service providers listed in Figure 3.8 target sorghum grain producers. It is evident, however, from discussions in Section 3.3.1 that they are unable to meet the requirements of especially smallholder farmers. There is a network of agri-inputs dealers in both rural and urban areas. These are involved in the government's flagship PFJ programme under which inputs can be accessed at heavily subsidised prices (50%). Anecdotal evidence obtained during the second mission in October indicates that there are some availability challenges, especially in the supply of fertiliser to the smallholder farmers.

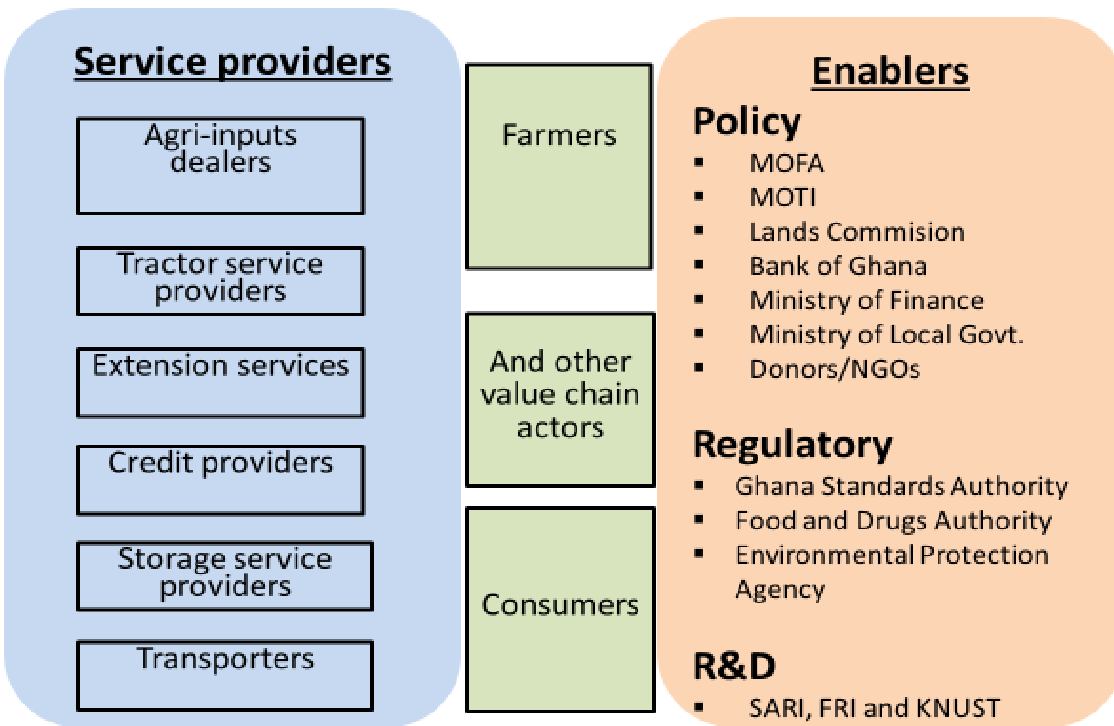


Figure 3-8: Service providers and enabling/regulatory institutions in Ghana's Sorghum Value Chain
Source: Authors

The commercial farmers consulted did not appear to face the same problem. The most common challenge in terms of inputs availability has to do with viable sorghum seed suited to the agro-climate in the sorghum producing areas. It is also evident that even when fertiliser is available at "affordable" (subsidised) price, severe household liquidity constraints during the planting season make it very difficult for smallholder farmers to buy. It is mainly the smallholder farmers who are supported under schemes similar to what is described in Box 3.1 who are able to buy fertiliser under PFJ. The support is extremely limited as it covers requirements for only one acre even though farmers are entitled to allocations for five acres under the PFJ.

In the savanna belt where sorghum production is concentrated, the use of tractor services for ploughing and harrowing is quite common, unlike the situation in the southern regions in Ghana. However, most smallholder farmers cannot afford this service, mainly due to the liquidity constraints which limit access to fertiliser and other inputs under the PFJ. Again most of the smallholder farmers who use tractor services for sorghum cultivation are those who are supported by aggregators and commercial farmers. The support is limited to one acre and is only for ploughing and no harrowing or mechanised planting.

Extension services are, in theory, available to smallholders and commercial farmers but in practice the evidence suggests access is severely limited. Smallholders involved in schemes linked to aggregators and commercial farmers may have access to external personnel facilitated. This includes advisory services provided under programmes such as MOAP. The commercial farmers are less constrained because some their staff are trained agronomists and others have "engaged" national service personnel to provide extension services. The overall quality of the extension advice provided requires a review and/or revision. This is particularly needed to build/strengthen the capacity of farmers to manage pre and post-harvest risks faced by the farmers. Climate change, especially weather variability in the form of erratic rainfall, is one of the main challenges which farmers are facing.

Lack of finance is a problem at all levels in the sorghum value chain with the probable exception of the industrial brewery. This has not emerged as an issue from our consultation with them and is most likely due to better access to commercial finance when needed and also the fact that they are able to obtain trade credit (ranging from 30 to 90 days) at zero interest.

Storage services appear to be relevant at the level of aggregators and the commercial farmers. Most of them do not have proprietary storage facilities. Even where they have access to warehouses, it is quite evident that supporting institutional infrastructure in the form of a robust regulatory system which will enable them collateralise stocks is absent. Resolving that can ease liquidity constraints within the trade.

3.4 Types of constraints and risks faced by actors in the sorghum value chain

In this section we highlight the main constraints and risks faced by different categories of players at different levels in the sorghum value chain in Ghana.

3.4.1 Constraints and risks at the level of sorghum grain production

Weather risks

As noted in Section 2.3.5, at the level of production sorghum, farmers are highly vulnerable to natural risks such as weather as well as pests and diseases. We noted in Section 2.3.1 that Ghana has become dryer with annual rainfall during the past decade (2008-2017) being about 8% less than the 30-year average. The decline in volume of rainfall has been even more severe in Northern Ghana, falling by over 15% (from average of 1,030 mm to about 875 mm). However, since sorghum is a drought-tolerant crop, this does not appear to be seen by sorghum farmers as a major threat. They are more concern about erratic rainfall, especially late rains occurring during the harvest season. This happened during the October 2019 harvest. It makes field drying of the crop extremely difficult, leading to mouldiness and increased incidence of aflatoxin contamination, which results in rejection by the breweries.

The main available solution to this challenge is in harvesting the mature crop even if it is raining and undertaking off-farm drying, for example using tarpaulins (Figure 3.9). For commercial farmers (CFs), getting sufficient labour for harvesting quickly is a major challenge. This is because, as noted above, most farm workers and temporary rural workers (described as *by-day labourers*) have their own farms and therefore ensure that they have completed harvesting their crop before offering labour for others. The delay in harvesting accentuates the quality problems mentioned above. It is for this reason that the CFs, who lack access to combine harvesters, are scaling back production and relying more on outgrowers.

SHF1 farmers also have similar challenges in off-field drying as they do not have access to tarpaulins. Some may dry the crop on the ground, leading to contamination with foreign matter. It is mainly the LMF and SHF2 farmers who are supported who are able to carry out off-farm drying according to requisite best practice.

Figure 3-9: Women harvesting and drying sorghum grain in Upper West Region, Ghana
Source: Authors (October 2019)

Crop pests and diseases
Fall armyworm and birds are major pests in sorghum production. In particular, the challenge in bird control appears to discourage seed producers from producing under irrigation during the dry season. This risk is particularly acute in the case of the white, relatively sweeter improved varieties preferred by the breweries (not pito brewers).

Limited access to inputs
Despite efforts by the GOG to increase access to yield-enhancing inputs such as fertiliser and pesticides, it was apparent from the team's interaction with farmers and other players that the majority SHF1 farmers could not access these inputs mainly because they lack the means to pay the required 50% of the price. Among smallholder farmers only the supported SHF2 manage to obtain the inputs under PFJ. This is despite that fact that better-endowed farmers (LMFs and CFs) who are not similarly constrained are able to obtain subsidised inputs under PFJ. This liquidity-related limitation to inputs access needs to be addressed with appropriate financing package – discussed in Chapter 7.

Access to improved seed is also a major challenge. SARI, which is the main public institution involved in crop breeding, faces a number of constraints including staffing and funding. As a result most of the farmers rely on retained seed. Where improved seed has been supplied, it has been from imported stock and reports indicate that these under-perform in terms of germination or are not suited to the climate, leading to very high harvesting and/or postharvest losses. Currently, efforts by SARI in breeding have focused on the white varieties for industrial brewing. It is important that attention is also paid to the supply of improved red varieties, which are more popular with the SHF1 farmers.

Other production risks and challenges
These include limited access to extension services and high postharvest losses due in part to variability in the weather at harvest as well as lack of suitable storage facilities. In addition farmers and farm workers are exposed to human health risks due the potential of being bitten or stung by snakes and scorpions with first-aid kits being largely unavailable. Farmers and other stakeholders consulted cited access to health services as a key challenge. This is despite the investment by the Government of Ghana in the Community Health Improvement Service (CHIPS) compounds, which are intended to provide health services to people in rural communities. According to some public officials consulted, this situation was partly due to difficulties in recruiting and retaining the requisite health personnel.

The recent Coronavirus (COVID-19) pandemic has highlighted a major vulnerability to such human health risks in agricultural value chains, including the sorghum value chain. This is not exactly new in West Africa. For instance, the Ebola virus disease (EVD) affected both rural and urban communities in Liberia, Guinea and Sierra Leone in 2014/15. It resulted in a steep decline in agricultural output and also had significant adverse effects on rural household incomes[19]. In the case of COVID-19, though the incidence in rural communities in Ghana has reportedly been low, it is apparent agriculture has affected by some of the measures implemented by the Government to contain its spread. In the sorghum value chain, these effects may not have occurred during the specific period in which this study was undertaken but are, without doubt, relevant to the long-term sustainability of the emerging modern sub-chains within it. For this reason, we assess the impact of COVID-19 on activities in the chain in Section 7.4 of this report.

3.4.2 Constraints and risks at the level of sorghum grain distribution and marketing

The main challenges and risks identified at the level of sorghum grain distribution and marketing include limited access to modern storage infrastructure, which contributes to high postharvest losses. Access to trade finance is also limited and, even when available, the cost of borrowing is considered by many of the traders and distributors as being quite high.

In the predominant informal trading system, transactions tend to be largely cash-based, making liquidity constraints even more acute for the traders. In the emerging Sub-chain 3, large-scale aggregators and the farmers supplying to them are required to extend trade credit (minimum of 30 days) to the industrial brewery. This creates major liquidity problems for the aggregators and the farmers, especially when payments are delayed well beyond the 30 days as was reported by some of the farmers consulted. Payments are made by cash, a situation which exposes the aggregators to high risks.

One uncertainty mentioned by aggregators consulted is whether GGBL will remain committed to the use of the sorghum grain. There is no evidence that it will switch but being the only major formal buyer creates this risk which may be mitigated by entry of other formal buyers.

3.4.3 Constraints and risks at the level of sorghum processing

Currently, pito is the largest absorber of sorghum. As a low-cost, energy and nutrition-rich, low alcohol drink, there is potential for consumption to grow. However, the perception that its consumption is mainly in Northern Ghana has fettered growth in demand in Southern Ghana. Even in Northern Ghana, demand for non-alcoholic pito is stymied as a result of religious traditions – by both Muslim and Christian leaders (the two predominant religions in the Northern Regions).

Pito has a rather short shelf-life (about 3 days). Hence the brewers tend to brew almost every day. Pasteurisation offers a means to lengthen its shelf-life but the cost of the technology and accompanying packaging appears to be a major hurdle.

Small-scale processing of sorghum into flour for preparation of meals occurs both in the North and in urban communities in the South. However, it remains at very micro-scale. One of the main constraints facing processors who are keen to scale up production is the level of investment required in setting up a processing plant which is compliant with standards set by the Ghana Standards Authority and the Food and Drugs Board. In addition, reliance on the informal supply chain for raw materials (sorghum grain) exposes the processors to variability in the quality which can impact on their products. The expectation is that as the Sub-chain 3 expands this problem will be mitigated.

3.5 Value chain governance and coordination

The form of value chain governance, as noted by Gereffi et. al (2005), influences activities required to bring a product or service to its end use. Two distinct governance systems are identified in the sorghum value chain in Ghana. The first, which is market governance, applies to Sub-chains 1 and 2 whilst the second – hierarchical governance – is identified with Sub-chain 3.

3.5.1 Market governance in Sub-chains 1 and 2 in the sorghum value chain

Market governance typically involves relatively simple transactions which are influenced principally by price. Access to these sub-chains appears to be largely unfettered because the main product – red varieties of sorghum grain used for pito brewing and for food at household level – is largely undifferentiated in terms of quality and related price premium. Entry barriers at the level of production and also utilisation of the crop are rather low leading to highly inclusive sub-chains. However, trade margins tend to be rather tight except at the level of pito brewing, which requires relatively more capital in setting up.

Where equity appears to be a constraint, as is in the case of pito brewing, embedded relational linkages tend to lower barriers to entry. This governance system, which is often trust-based, emerges to govern interactions between players in

[19] Gatiso TT et al. (2018) "The impact of the Ebola virus disease (EVD) epidemic on agricultural production and livelihoods in Liberia". PLOS Neglected Tropical Diseases 12(8):

value chains. Apart from enabling daughters to takeover sorghum trading and pito brewing, relational linkages also lower barriers for parties who may not be related by blood but are required to transact on repeated basis for mutual benefit. Examples include traders who buy on credit from wholesalers in urban markets, paying for stocks after sales, often at the end of the day. Pito brewers may similarly buy malted sorghum on credit from blood relations or long-term trade partners, settling any debts soon after selling of the batch of pito brewed. Such relational linkages are, however, rare between farmers and rural traders (micro-scale collectors or small-scale aggregators). The absence of this system contributes to illiquidity in the rural trade in sorghum.

3.5.2 Hierarchical governance in Sub-chain 3 in the sorghum value chain

Hierarchical governance is characterised by vertical integration within the value chain and evident in Sub-chain 3. The system centres around an agent with visible market power, in this case the industrial brewery, which defines the incentive framework for participation primarily through pricing. It is apparent that farmers perceive Sub-chain 3 as competitive in terms of the farmgate prices offered. In addition, the fact that the prices are meant to be announced prior to planting provides certainty as far as household income expectations are concerned. In addition, bulk sale of the crop soon after harvest implies that farmers have access to lumpy farm income which can be invested in other activities whilst also minimising postharvest losses as they don't have to hold stocks for a long period.

However, to gain the perceived benefits, it is clear that suppliers have to comply with stringent quality standards set by the industrial brewery. The standards include type of variety cultivated and the enforced produce quality parameters, which include maximum levels of acceptable moisture content, foreign matter and aflatoxin levels. These standards have the potential to screen out some farmers and traders. For example, during a visit to a warehouse belonging to Agriaccess, it emerged that with grains supplied by micro-collectors and small-scale aggregators, about 12% represent material which is deemed as "waste" or "out-grades". This aggregator, however, confirmed that their experience with farmers linked to them is very different. The reasons for this situation include training offered to the farmers as well as price incentives for supplying quality produce with minimum risk of being cheated on weight as trade is based on standardised weights rather on volumetric measures. It is evident that the relational linkage between smallholder farmers and aggregators, involving community-based lead farmers, has contributed to the development of smallholder farmers' capacity to stay in the sub-chain, thereby ensuring inclusiveness.

3.5.3 Fostering growth in Sub-chain 3: role of regulatory agencies

The product quality standards, which the industrial brewery has to comply with are enforced by the Ghana Standards Authority (GSA) and the Food and Drugs Authority (FDA). These standards are important in sustaining consumer confidence in the products marketed by the industrial brewery and in order to maintain its market share. The regulatory enforcement does not only apply to the final products marketed but also the process through which they are produced and the raw materials used for brewing. This is the main reason why the brewery has to enforce stringent produce quality standards for the sorghum it is procuring from the local market. However, as noted above, enforcement of these standards doesn't necessarily have to lead to the exclusion of smallholder producers because training and maintenance of appropriate price incentives tend to foster effective compliance capacity.

It is anticipated that growth in the supply of quality sorghum grain will encourage investment in medium to large-scale processing of sorghum grain into various food products. We have noted, however, that this is not happening due to the limited capacity of existing micro-scale processing companies to invest in manufacturing facilities which are compliant with the requirements set by the standards authorities. This is an area worth further discussion as we initiate in Chapter 7.

Though the EPA is expected to impact the operations of all actors in the value chain, it is evident that their influence is felt mainly at the level of major sorghum end-users such as industrial breweries. The standards authorities are also clearly impacting on the pace at which formal processing of sorghum into food products will grow in the country. The evidence obtained so far indicates that regulatory enforcement constitutes a major bottleneck and that proactive actions to enable investors overcome this challenge is needed to spur inclusive growth in this segment. We discuss some of these options in Chapter 7.

3.5.4 Enabling actions to foster growth in sorghum value chain

Promoting access to yield-enhancing inputs

One of the flagship initiatives by the Government of Ghana (GOG) is the Planting for Food and Jobs (PFJ) programme. Under PFJ the GOG is distributing improved seed, fertiliser and pesticides to farmers, including sorghum producers. The subsidy of 50% aims to address farmers' affordability challenges but, as reported above, the farmers also face acute liquidity problems during the planting season which makes it difficult to buy the inputs allocated to them. Partly as a result of this, leakage of the subsidised inputs into untargeted markets, including some in the sub-region, has reportedly become a challenge for managers of the PFJ. It is, therefore, worth exploring options to reduce farmers' liquidity constraints by developing financing packages which enable them pay for the inputs after harvest rather than upfront during the planting season. This is explored further in Chapter 7 and involves exploring roles which can be played by other ongoing initiatives such as the rural banking system in the country as well as the Ghana Agricultural Insurance Pool (GAIP) and the Ghana Incentive-based Risk Sharing System for Agricultural Lending (GIRSAL) Programme.

Assuring consistent supply of improved seed

As far as agronomic research on sorghum is concerned, it is the Savanna Agricultural Research Institute (SARI) which has the statutory mandate. The most significant research efforts at improving sorghum and pearl millet have been undertaken through SARI's Sorghum and Millet Improvement Programme with funding from the Ghana Government and GIZ. The objective of the sorghum improvement programme (which started in the late 1960s) was to develop high yielding varieties of sorghum with specific adaptation to different ecological conditions of the savanna. Specifically, the sorghum and millet research programme has aimed at developing early and medium maturing varieties that have good grain quality and are resistant or tolerant to the major pests and diseases which normally affect sorghum, including the striga weed. From consultations with officials of SARI, they have significant staffing and resource constraints in carrying out their mandate. This is limiting their ability to facilitate improved availability of viable, high-yielding sorghum seed. It is also apparent that the focus of SARI seed improvement efforts is on varieties preferred by the formal breweries. There is however the need to broaden their efforts to cover the red sorghum varieties preferred by the traditional pito brewers as that segment of the market remains the most dominant.

Among some of the stakeholders consulted, there was a view that seed producers could take advantage of the GOG's One Village One Dam (1V1D) to cultivate sorghum seed during the dry season. Though this may be technically feasible, in terms of water availability for plant growth, the high risk of pre-harvest losses from bird pests raises major doubts about its financial viability. Hence, we do not anticipate that the sorghum value chain will benefit significantly from this initiative though other crops and especially vegetables may benefit.

Improving postharvest produce handling

The One District One Warehouse (1D1W) launched by the GOG is expected to improve postharvest crop handling by making available modern, off-farm storage infrastructure. In Figure 3.9 is one such facility constructed close to Sabuli where there is a group of sorghum farmers linked through Agriaccess to the Sub-chain 3. The facility has storage capacity of about 1,000 tonnes and is reportedly to be made available to the Ghana Commodity Exchange (GCX) for holding stocks to be traded on its floor. Under this arrangement, Agriaccess and other aggregators may not have access to the facility, especially as prices for sorghum are pre-negotiated and therefore highly unlikely to be traded on the exchange floor. It is for this reason that Agriaccess is investing in proprietary storage infrastructure within 20 kilometres of the GOG-funded facility. This will enable it have unfettered access to storage.

Figure 3-10: Warehouse under construction near Sabuli in Upper West Region, May 2019
Source: Authors

Fostering value addition through investment in processing facilities
The One District One Factory (1D1F) programme is another of the GOG flagship initiatives. The objective is to promote value addition in rural-based value chains and to generate employment. It is unclear how sorghum processors can benefit from this initiative, especially as they generally start operating from facilities at or near their homes in urban areas. Perhaps one option will be for GOG to promote incubation investment in the form of processing infrastructure which can be rented to investors to enable them start off – in particular through easing compliance with process-related requirements for licensing products. This is taken up in more depth in Chapter 7.

One other area the public sector can assist in scaling up processing in sorghum and other agricultural value chains is to leverage the capacity of the Food Research Institute (FRI) to undertake product development. Most SMEs lack the resources to effectively undertake research and development. Even if they do, the ease with which others will free ride the outcome of their investments in that makes it financially unrewarding. Hence, public investment in such an activity as is the mandate of FRI is clearly justifiable on public goods grounds. However, the drive to achieve financial sustainability as is the case with all institutions under the Council for Scientific and Industrial Research (CSIR), appears to have shifted the focus of FRI for fostering uptake of R & D outcomes to marketing products. There may be the need to re-visit this policy in order to optimise benefits to agro-based industries in the country.

4 ECONOMIC ANALYSIS OF SORGHUM VALUE CHAIN

4.1 Introduction:

The economic analysis reported in this chapter is intended to answer two key framing questions:

- What is the contribution of the sorghum value chain to economic growth in Ghana; and
- Whether growth in the chain is inclusive.

In accordance with the standard methodology, answering these questions involved the following:

a. Undertaking financial analysis of the key actors
b. Assessing overall effects on the national economy
c. Analysing the sustainability and viability of the chain within the international economy
d. Assessing the inclusiveness of growth in the chain

Consistent with the adopted methodology, the bulk of the analysis is based on market prices. The key actors covered are stated in Section 3.2 of this report.

4.2 Financial analysis of operations of the key actors:

The financial analysis involves assessing how profitable the key actors are. The main tool of analysis is the operating account, which takes into account only flows involving market exchange and therefore applies actual market prices. The methodology used in the financial analysis centres around computation of operating accounts of key actors in the value chain as shown in Box 4.1 below.

Box 4.1: Computation of operating accounts of key actors

Value chain agents' operating accounts have been calculated based on the following outline:

Revenues
Production / output
- Sales
- Self-consumption
- Stocks variation

Direct subsidies

Expenses
(Cost of Production)
- Intermediate Goods and Services
- Value Addition (direct VA)
    - Value of rented land
    - Value of hired labour
    - Financial charges
    - Taxes / duties
    - Depreciation
    - Net profit

Source: Based on VCA4D Methodological Framework.

The analysis based on this computation makes it possible to answer the core question of how profitable and sustainable the activities in the sorghum value chain are for the actors involved. The analysis generates information on the overall net income for each category of actors as well as on per capita basis. The latter makes it possible to compare income per individual entity or household with benchmarks such as national minimum wage or national living wage. Profitability is also assessed in terms of returns per applicable benchmarks. Due to difficulties in obtaining details on actual capital investments by the key actors, the main benchmarks used in assessing overall financial performance of the actors is return on turnover (net profit/ marketed output). In this computation, household consumption is included, and the producer price obtained at the respective level is applied. Such a rate may be relatively more important for larger-scale operators, for whom it represents an indication of the efficiency of their operation. For the smaller-scale actors in the chain, the extent to which income generated from the chain contributes to overall household income and wellbeing may be the more relevant issue.

In particular case of sorghum grain producers, we deliberately benchmark the profitability assessment against marketable output as well as the total value of output per category of farmers. This is because the volume of postharvest losses occurring in the value chain is significant and the latter computation makes it possible to assess the potential benefits of postharvest loss-reduction interventions and/or investments. Furthermore, we stated in Section 1.3.3 that industry-wide data is used in carrying out financial analysis of the operations of industrial brewery in order to avoid the risk of disclosure of commercially-sensitive information and also to overcome data access challenges created as a result of the difficulty in isolating brewing with sorghum from the overall operations of the brewery.

4.2.1 Producer margins and earnings in the sorghum value chain

Table 4.1 below shows that sorghum production by all categories of farmers is profitable. The average return on turnover for sorghum grain producers is about 23%. However, profitability varies across the different types of producers. For instance, the return on turnover for the low-input, low-cost mainstream smallholder farmers (SHF1) is 22.3%. The emergent smallholder farmers (SHF2) are marginally more profitable, posting a return on turnover of 24.2%. The respective rates of return for lead and medium-scale farmers (LMF) as well as commercial farmers (CF) are: 18.9% and 48.1%.

Subsistence[20] at SHF1 level not sustainable

The SHF1 producers are profitable despite the productivity of their sorghum farms being very low – estimated at about 0.65 tonnes per hectare compared to the official estimated average yield of 1.2 tonnes per hectare. They do not cultivate high-yielding seed and, in general, do not use fertiliser and pesticides in the production of sorghum. Their operation is profitable mainly because of the very low costs since they do not spend on inputs such as fertiliser and seed as well as on the labour required to apply them.

It is evident from the available evidence that the farm income SHF1 farmers obtain from sorghum production cannot sustain a family. The sorghum-based income they obtain is estimated at GHS 215 (equivalent to $45 or €40), per annum per farmer. Most SHF1 allocate only 30% of the land cultivated to sorghum, as shown in Table 3.2, the remainder of the land being used to grow maize (50%) and other crops (20%). Based on this, we project that the SHF1 farmers will obtain annual farm income of about GHS 715 ($149 or €132) if they commit 100% of their cultivated land to sorghum (at the same yield levels). This is about 45% below the national poverty line estimated at GHS 1,315 in 201721 and far below the annual income earned by workers receiving the national minimum wage, which is estimated at GHS 3,065 ($640 or €565) per annum as reported in Section 5.3.1 (under the Social Analysis). Hence, crop diversification appears to be a good strategy to mitigate the potential risk of income, and possibly, food insecurity which the SHF1 farmers may face.

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[20] *The term subsistence used in this context to mean maintaining or supporting the farm household at the minimal level of income generated.*

[21] *Source: Ghana Statistical Services (2018) "Ghana Living Standards Survey Round 7: GLSS7 – 2005-2017).*

Table 4-1: Operating accounts of producers of marketable volumes of sorghum in Northern Ghana (in GHS in 2018)

Item/producer		Smallholder farmers (SHF1)	Smallholder farmers (SHF2)	Lead/medium-farmers (LMF)	Commercial farmers (CF)	Sub-total for farmers
Total revenues (value of production)		**165,056,883**	**120,716,579**	**4,886,561**	**2,042,443**	**292,702,466**
	Sales	84,402,500	75,335,364	3,900,000	1,890,690	165,528,554
	Self-consumption	80,654,383	39,362,076	458,900	36,594	120,511,953
	Subsidies	-	6,019,139	527,661	115,159	6,661,959
Intermediate goods and services (total)		**64,175,671**	**48,368,019**	**1,852,770**	**385,524**	**114,781,983**
	Seed	-	2,830,871	117,667	25,680	2,974,218
	Fertiliser	-	7,666,941	780,767	170,398	8,618,106
	Pesticides	-	1,540,465	156,889	34,240	1,731,594
	Transport	7,971,601	6,709,163	223,331	48,741	14,952,836
	Bagging materials	2,930,070	132,343	83,838	18,297	3,164,548
	Utilities	-	-	-	4,280	4,280
	Ploughing	53,274,000	29,488,235	490,278	83,888	83,336,401
Value added (direct)		**100,881,212**	**72,348,560**	**3,033,791**	**1,656,919**	**177,920,483**
	Value of rented land	-	-	-	42,800	42,800
	Value of hired labour	44,931,958	30,343,394	1,585,558	440,412	77,301,322
	Financial charges	15,982,200	9,966,363	370,944	83,788	26,403,295
	Local council levies	350,595	481,248	70,600	21,400	923,843
	Taxes/duties	-	-	-	-	-
	Depreciation	2,726,955	2,368,643	83,396	85,600	5,264,594
	Net profit	36,889,504	29,188,912	923,293	982,919	67,984,629
Return on turnover (%)		22.3	24.2	18.9	48.1	
Income per household (GHS)		213.06	618.67	2,637.98	245,729.75	

Source: Authors

Operations of supported smallholder farmers (SHF2) shows potential for poverty reduction

We reported in Box 3.1 that SHF2 farmers are assisted with inputs credit delivered by large-scale aggregators and commercial farmers. These actors leverage funding for this from projects such as the MOAP-supported Revolving Fund and the OVCF. The credit is to enable these farmers to acquire and utilise inputs supplied under PFJ as well as for ploughing. Repayment in the form of sorghum grain delivered to the aggregators or commercial farmers during the harvest season. The support provided is however limited to requirements for one (1) acre of cultivated land though under the PFJ farmers are entitled to inputs for five (5) acres.

The most interesting impact of the support provided is not the rather marginal increase in profitability as the return on turnover rises from 22.3% to 24.2% but the significant rise in household income from sorghum production result from it. As reported in Table 4.1, annual income obtained by SHF2 farmers from sorghum production is just over double what the SHF1 farmers get, i.e. almost GHS 620 (or $129 or €115). They tend to increase area planted with sorghum from 30% to about 40% of the total land area they cultivate and also record overall increase in yield per hectare by about 30% – from an average 0.65 tonnes to 0.825 tonnes per hectare due to the effects of either spreading the fertiliser they receive over a wider area than recommended or the compensatory effects of variable yields from different portions of the field. The result of the upscaling of area cultivated and rising farm productivity is a doubling of total marketable surplus to about 2.1 tonnes per household. Furthermore, due to the fact that they are linked with aggregators, they are able to sell into the emerging Sub-chain 3, which offers a producer price of GHS 1.3 per kilogram of sorghum grain (about 20% higher than what is obtained by SHF1 farmers selling to rural collectors in Sub-chain 1).

It is the combination of the above factors which makes it possible for the SHF2 farmers to obtain substantially higher income from sorghum production than their counterparts (SHF1 farmers). We project that if they commit 100% of their area planted to sorghum, they can obtain about GHS 1,545 ($322 or €287) per annum. This is above the national poverty line but remains below the annual minimum earnings from wage labour (the minimum wage per annum is GHS 3,065 or (i.e. $640 or €565). The possibility of earning comparatively higher income than SHF1 farmers is attracting some youth to participate in some of the outgrower schemes run by the large-scale aggregators and commercial farmers in sorghum. As reported in Section 5.1, they can also earn farm-wage income as part-time workers for the commercial farmers.

Sorghum farmers who are able to take up the full complement of their allocation of fertiliser and other inputs under the PFJ are significantly more productive than other smallholder farmers. They fall within the group we categorise as lead/medium-scale farmers (LMF), cultivating a total of 9-10 hectares, out of which 60% (about 5.5 hectares) is dedicated to production of sorghum for supply into Sub-chain 3. They tend to be better endowed than the average smallholder farmer and generally enter into farming with resources generated from formal employment or other business activities, as noted by Jayne et al (2016)[22]. Their ability to apply inputs at the recommended rates enables them to obtain average yields of about 1.8 tonnes per hectare of sorghum. Though substantially higher than the average for SHF2 farmers, this yield is lower than what the better-endowed commercial farmers obtain – i.e. about 2.5 tonnes per hectare. This is partly because they sometimes have challenges in accessing inputs and on time – especially top dressing fertiliser.

The LMF sell directly into Sub-chain 3 and, on the average, earning close to GHS 2,640 per season from sorghum production (i.e. about $550 or €490). We project that if they planted 100% of their land with sorghum, then earnings from sorghum production could exceed GHS 4,400 (equivalent to $915 or €815), implying that the households can subsist on income from sorghum production alone. However, it has to be acknowledged that this is still lower than then annual living wage, estimated at just over GHS 10,000 (or $2,085 or €1,850).

Sorghum seed producers have not been included in computations of direct value added to the grain value chain but rather in the providers of intermediate goods and services to the key actors. For this reason, details of their operating accounts are not included in the analysis. However, it emerged from consultations of some sorghum seed growers that they tend to cultivate about 20 hectares on the average and generate annual net income of about GHS 10,500 (or $2,185 or €1,945). This is above the annual national living wage.

Direct income from sorghum production earned by commercial farmers, with an average of 100 hectares under sorghum, is estimated at GHS 245,730 (or $51,200 or €45,500) per annum per operator, making it an attractive commercial investment generating more than 20 times the annual living wage in Ghana.

[22] It must be noted that this group of farmers are at the lower end of the typical medium-scale farmer, defined by Jayne et al. (2016) as farmers with holdings above 5 hectares and below 100 hectares.

4.2.2 Margins and net incomes at the level of distributors (aggregators and traders)

Table 4.2 shows that margins in the distribution segments of the sorghum value chain are much tighter than at the production level. The average return on turnover for this segment is about 6.2% compared to about 23% at the level of production. The relatively tighter margins reflect the level of competition in the trade.

Rural collectors, who tend to be community-based micro-traders, obtain an average return of 8.9% on their turnover. The average sorghum-linked trade income per collector is about GHS 4,828 (i.e. just over $1,000 or close to €900) per annum. This is higher than average farm income earned by most smallholder producers, though slightly lower than the farm earnings obtained by the LMF. Small/medium-scale aggregators post an even tighter return of only 3.9% but the annual income generated for these traders is about GHS 14,320 (i.e. about $2,980 or €2,650). This income is above the national living wage.

Lead farmers, who bulk sorghum grain from SHF2s farmers on behalf of aggregators and commercial farmers, incur relatively low operating costs because they actually do not trade but bulk on behalf of their principals for a commission of about 4.5% of the volume handled. Their role also involves intensive mobilisation and monitoring the activities of the participating SHF2 farmers to secure supplies as well as ensure repayment in-kind of the inputs credit provided. The commission fee they earn is about GHS 5,015 (i.e. about $1,040 or €980) per annum. Adding this to their farm income, reported above (Section 4.2.1), brings their total annual income to GHS 7,080 (i.e. about $1,470 or €1,310), which is just above the threshold of the national annual living wage.

Large-scale aggregators are contracted to the industrial brewery and negotiate central contracts with fixed prices and margins, including what is paid to the smallholder producers. They earn on the average about GHS 470,800 (i.e. about $97,880 or €87,185) from selling sorghum grain to this formal offtaker[23]. It is apparent aggregating by commercial farmers under their outgrower schemes is highly profitable, with a return of turnover of estimated at 8.7%. It is also evident that the specialised large-scale aggregators are also being encouraged by the incentive structure in Sub-chain 3 to invest in scaling up as well as upgrading their operations.

Wholesalers in urban markets have not been significantly engaged in the formal sorghum grain trade, involving marketing of graded grains in Sub-chain 3. Their trade, which predominantly targets retailers, pito brewers and small-scale processors generates annual earnings from the sorghum grain estimated at about GHS 76,260 (i.e. about $15,850 or €14,120). Sorghum grain retailers also earn about GHS 1,345 (i.e. $280 or €250) per annum from selling this crop. However, as noted in Section 3.3.2 they usually sell other grains, with sorghum representing not more than 20% of the total volume of grains they trade.

[23] *Note that this computation includes trade margins on crop produced directly by the commercial farmers.*

Table 4-2: Operating accounts of sorghum grain distributors (aggregators and traders) in Ghana (in GHS in 2018)

Item/value chain actor		Lead farmers	Rural collectors	Small/medium aggregators	Large-scale aggregators	Grain wholesalers	Grain retailers	Sub-total
Total revenues (value of production)		**1,768,000**	**95,238,000**	**180,870,000**	**32,300,000**	**235,131,000**	**46,956,000**	**592,263,000**
	Sales/commission	1,768,000	95,238,000	180,870,000	32,300,000	235,131,000	46,956,000	592,263,000
	Self-consumption	-	-	-	-	-	-	-
	Subsidies	-	-	-	-	-	-	-
Intermediate goods and services (total)		-	**83,076,840**	**163,988,800**	**24,627,900**	**189,913,500**	**44,469,516**	**506,076,556**
	Sorghum grain	-	79,120,800	156,754,000	22,100,000	180,870,000	42,588,000	481,432,800
	Transport	-	-	6,029,000	1,635,400	-	436,800	8,101,200
	Utilities	-	-	422,030	892,500	-	-	1,314,530
	Other costs	-	3,956,040	783,770	-	9,043,500	1,444,716	15,228,026
Value added (direct)		**1,768,000**	**12,161,160**	**16,881,200**	**7,672,100**	**45,217,500**	**2,486,484**	**86,186,444**
	Value of rented land	-	-	-	549,780	5,849,336	141,261	6,540,377
	Value of hired labour	765,000	2,197,800	3,617,400	1,020,000	-	-	7,600,200
	Financial charges	-	-	4,898,563	2,357,333	21,704,400	-	28,960,296
	Local council levies	-	1,465,200	1,205,800	170,000	1,205,800	218,400	4,265,200
	Taxes/duties	-	-	-	665,210	-	-	665,210
	Depreciation	-	-	-	85,000	1,205,800	109,200	1,400,000
	Net profit	1,003,000	8,498,160	7,159,438	2,824,777	15,252,164	2,017,623	36,755,161
Return on turnover (%)		4.5	8.9	3.9	8.7	6.5	4.3	
Income per household (GHS)		5,015	4,828	14,319	470,796	76,260	1,345	

Source: Authors

Table 4-3: Operating accounts of sorghum grain transformers (brewers/processors) in Ghana (in GHS in 2018)

Item/producer		Pito brewers	Microbrewers	Industrial brewers	Grain processors	Sub-total
Total revenues (value of production)		**543,620,000**	**921,000**	**574,200,000**	**2,756,250**	**1,121,497,250**
	Sales/commission	469,490,000	900,000	561,600,000	2,756,250	1,034,746,250
	Self-consumption	24,710,000	-	-	-	24,710,000
	Spent grain/by-products	49,420,000	21,000	12,600,000	-	62,041,000
	Subsidies	-	-	-	-	
Intermediate goods and services (total)		**343,617,260**	**532,500**	**351,000,000**	**1,338,750**	**696,488,510**
	Sorghum grain	192,738,000	64,500	34,200,000	682,500	227,685,000
	Other ingredients etc.	148,260	213,000	174,600,000	-	174,961,260
	Transport	9,884,000	60,000	36,000,000	26,250	45,970,250
	Milling/malting	7,413,000	21,000	5,400,000	35,000	12,869,000
	Utilities (water/electricity)	9,884,000	99,000	59,400,000	288,750	69,671,750
	Firewood	118,608,000	-	-	-	118,608,000
	Packaging and other costs	4,942,000	75,000	41,400,000	306,250	46,723,250
Value added (direct)		**200,002,740**	**388,500**	**223,200,000**	**1,417,500**	**425,008,740**
	Value of rented land	-	315	189,000	-	189,315
	Value of hired labour	44,478,000	19,440	2,916,000	26,250	47,439,690
	Financial charges	-	-	44,100,000	-	44,100,000
	Local council levies	988,400	450	360,000	5,250	1,354,100
	Taxes/duties	-	225,000	108,810,000	-	109,035,000
	Depreciation	15,400,000	43,500	26,100,000	35,000	41,578,500
	Net profit	139,136,340	99,795	40,725,000	1,351,000	181,312,135
Return on turnover (%)		25.6	10.8	7.1	49.0	16.2
Income per household (GHS)		25,297	99,795	40,725,000	6,755	

Source: Authors

4.2.3 Processors margins and net incomes in the sorghum value chain

Table 4.3 above shows the operating accounts of entities engaged in transforming sorghum grain into consumer products. These are mainly brewers and processors in the sorghum value chain. The margins range from 7% for industrial brewers to about 49% for processors transforming the grain into flour for household consumption. The average return on turnover in this segment of the chain is about 16%.

Traditional pito brewing is shown in the analysis as being very lucrative. The return on turnover is almost 26%, and the operation generates annual income of about GHS 25,300 (i.e. about $5,260 or €4,680), which is more than double the national living wage. Entry barriers appear rather low as start-up capital for the basic equipment used for brewing is rather low – about GHS 2,800 ($590 or €520). Usually, daughters understudy the mothers and take time to build up capital. Similar opportunities are available to female “friends and relations” of brewers. Gender perception of involvement in pito brewing appears to be the main barrier.

Analysis of the operating accounts of pito brewers show that there is potential for it to become more cost-efficient if technologies are adopted which can improve fuel combustion efficiency. The main fuel used in brewing is firewood. Its cost accounts for almost 30% of the total operating cost in pito brewing. Modern earthen stoves, which have been tried by some pito brewers can potentially reduce firewood use and associated cost by about 50%. Furthermore, the technology, which requires about GHS 3000 (i.e. $625 or €560) in upfront investment, also reduces exposure to smoke inhalation (shown in Figure 5.2 in Chapter 5), thereby addressing one of the main hazards associated with the open firing systems (Figure 3.6), which is discussed in the Social Analysis. It is also evident that reduction in firewood combustion in brewing pito will lead to positive environmental outcomes through reducing direct emissions (see Chapter 6).

Sorghum processing appears quite lucrative, with return on turnover of close to 50%. Even at the micro-scale, it can generate GHS 6,755 (i.e. $1,400 or €1,250) per household per annum. Most of the actors engaged in this activity take it as a supplementary source of income, usually in addition to formal employment. However, processing remains at the micro-scale, mainly because of bottlenecks of a regulatory nature which make it difficult for investors to scale up operations.

Margins in commercial brewing of alcoholic and non-alcoholic beverages such as beer using sorghum post much tighter, with returns of about 7% for the industrial brewer and close to 11% for microbrewers. The comparative average return for pito brewing is about 25%. Commercial brewing with sorghum generates significant revenue and it is quite evident that the industrial brewery is committed to it and is likely to scale up utilisation in the medium-term (over the next 5 years).

4.3 Assessment of Sorghum VC contributions

In this section the analysis focuses on assessing the contribution of the sorghum value chain to economic growth in Ghana in terms of the nominal value of the contribution and as a share of the overall gross domestic product (GDP) as well as of agriculture sector GDP. Also assessed are the chain’s contribution to public finances, balance of trade and the extent to which it is integrated into the national economy.

The basis for computing value added in the sorghum value chain is data generated in the operating accounts, disaggregated into value of total production in the chain, intermediate goods and services (IGS) used and value added at different levels in the chain. Table 4.4 summarises the accounts for the key actors, providing details of the direct value added generated. In Table 4.5 breakdown of the IGS is provided, disaggregating it into imported IGS, remaining domestic IGS and value added by providers of goods and services. A summary of total (direct and indirect) value added in the chain is provided in Table 4.6.

Table 4-4: Consolidated operating accounts of main actors in sorghum value chain in Ghana, including direct value added (in GHS in 2018)

Item/value chain actor	Sorghum grain producers	Sorghum grain traders & distributors	Sorghum processors & brewers	SUB-TOTAL
Total revenues (value of production)	**292,702,466**	**110,830,200**	**893,812,250**	**1,297,344,916**
Sales/commission	165,528,554	110,830,200	807,061,250	1,083,420,004
Self-consumption	120,511,953	-	24,710,000.00	145,221,953
By-products (e.g. spent grain)	-	-	62,041,000.00	62,041,000
Subsidies	6,661,959	-	-	6,661,959
Intermediate goods and services outside VC*	**114,781,983**	**24,643,756**	**468,803,510**	**608,229,249**
Seed, fertiliser and pesticides	13,323,918	-	-	13,323,918
Transport	14,952,836	8,101,200	45,970,250	69,024,286
Bagging materials	3,164,548	-	-	3,164,548
Utilities	4,280	1,314,530	69,671,750	70,990,560
Ploughing	83,336,401	-	-	83,336,401
Other brewing ingredients	-	-	174,961,260	174,961,260
Milling/malting	-	-	12,869,000	12,869,000
Firewood	-	-	118,608,000	118,608,000
Packaging and other costs	-	-	46,723,250	46,723,250
Other costs	-	15,228,026	-	15,228,026
Value addition (direct VA)	**177,920,482**	**86,186,445**	**425,008,740**	**689,115,667**
Value of rented land/storage etc.	42,800	6,540,377	189,315	6,772,492
Value of hired labour	77,301,322	7,600,200	47,439,690	132,341,212
Financial charges	26,403,295	28,960,296	44,100,000	99,463,591
Local council levies	923,843	4,265,200	1,354,100	6,543,143
Taxes/duties	- 0	665,210	109,035,000	109,700,210
Depreciation	5,264,594	1,400,000	41,578,500	48,243,094
Net profit after tax	67,984,628	36,755,162	181,312,135	286,051,925

Source: Authors *Excluding value of sorghum grain supplied to distributors and transformers by domestic producers.

Table 4-5: Breakdown of intermediate goods and services (IGS) used in sorghum value chain in Ghana (in GHS in 2018)

	IGS imported	Local IGS	Land value	Labour value	Finance charges	Taxes/Dues	Depreciation	Gross profit	Total
Seed	29,742	446,133	59,484	1,338,398	297,422	- -	297,422	505,617	2,974,218
Fertiliser	5,170,864	689,448	-	1,034,173	775,629	- -	- -	947,992	8,618,106
Pesticides	1,038,957	138,528	-	207,791	155,844	- -	- -	190,475	1,731,595
Transport	24,128,370	8,554,361	-	6,255,849	7,255,849	9,383,773	7,190,235	6,255,849	69,024,286
Bagging/packaging/bottling	26,677,527	7,814,242	-	6,511,796	5,209,352	6,327,913	3,439,888	9,767,160	65,747,878
Ploughing etc.	29,167,740	8,333,640	-	10,000,368	7,083,595	10,000,368	8,333,640	10,417,050	83,336,401
Utilities	14,113,706	17,597,294	-	10,585,280	7,056,851	10,585,280	3,573,266	7,056,853	70,568,530
Other brewing ingredients	87,480,630	13,887,677	-	20,995,351	19,245,739	- -	- -	33,242,639	174,852,036
Milling	4,504,150	1,930,350	-	1,286,900	1,930,350	1,286,900	643,450	1,286,900	12,869,000
Fuelwood	5,930,400	23,621,600	-	35,582,400	11,860,800	11,860,800	5,930,400	23,721,600	118,508,000
	198,242,086	**83,013,273**	**59,484**	**93,798,306**	**60,871,431**	**49,445,034**	**29,408,301**	**93,392,135**	**608,230,050**

Source: Authors

Table 4-6: Summary of value added by actors in sorghum value chain in Ghana (in GHS in 2018)

Item/value chain actor	Direct value added by main actors				Indirect VA contributed by providers of goods & services[24]	Total
	Sorghum grain producers	Sorghum traders & distributors	Sorghum processors & brewers	Sub-total		
Value of rented land/storage etc.	42,800	6,540,377	189,315	6,772,491	59,484	6,831,976
Value of hired labour	77,301,322	7,600,200	47,439,690	132,341,212	93,798,306	226,130,517
Financial charges	26,403,295	28,960,296	44,100,000	99,463,591	60,871,431	160,335,023
Local council levies	923,843	4,265,200	1,354,100	6,543,143	-	6,543,143
Taxes/duties	-	665,210	109,035,000	109,700,210	49,445,034	159,145,244
Depreciation	5,305,542	1,400,000	41,578,500	48,284,042	29,408,301	77,692,343
Net profit after tax	67,943,681	36,755,161	181,312,135	286,010,977	93,392,135	379,403,112
Sub-totals	177,920,483	86,186,444	425,008,740	689,115,667	**326,974,691**	1,016,090,358

[24] *The value of IGS not disaggregated corresponds to GHS 83 million (source authors).*

4.3.1 Value added in sorghum value chain and its contribution to agricultural GDP

Ghana in 2018 produced a total of 278,000 tonnes of sorghum grain. Utilisation of the grain included household consumption, direct sale to consumers in both rural and urban areas for food as well as uptake by transformers producing sorghum-based products, especially the traditional pito and, more recently, beer and other non-alcoholic beverages. Processing the grain into flour for food is also emerging, though it remains on a very small scale. **Total value added** from production through distribution to transformation is estimated at **GHS 1,016.1 million** (i.e. $211.7 million or €188.5 million[25]) as reported in Table 4.6 above. **Direct value added** by the main actors in the value chain accounts for 68% of the total value added whilst the remaining 32% represents the contribution from suppliers of goods and services from outside of the value chain. A breakdown of the intermediate goods and services (IGS) used in the value chain, which is provided in Table 4.5 above. It shows that the imported component of the IGS is about GHS 198.2 million (i.e. $41.2 million or €36.7 million).

Official reports from the Ghana Statistical Services (GSS)[26] estimates the agricultural GDP in Ghana in 2018 at GHS 54.92 billion (i.e. $11.4 billion or €9.98 billion). Hence, the total value added in the sorghum value chain in 2018 represents ***almost 2.0% of the overall agricultural GDP in Ghana***. To put the contribution of sorghum in context cocoa, which is the most important cash/export crop in the country, in 2018 contributed GHS 4.34 billion (i.e. about $900 million or €870 million) or 7.9% of Ghana's agricultural GDP. The contribution from the sorghum value chain is, therefore, close to 25% of valued added in the cocoa subsector in Ghana. Cocoa attracts far more policy attention and public investment than the sorghum subsector, largely because of its importance in the generation of foreign exchange. However, there is potential for the contribution to agricultural GDP from the sorghum value chain to significantly increase in the medium term as discussed in Section 7.5.

4.3.2 Actors contribution to value added

Figure 4.1 shows the contributions of various groups of actors to value added in the sorghum value chain. The share contributed by sorghum grain producers is estimated at 18%, more than double the contribution from players in the distribution chain such as rural collectors, aggregators, wholesalers and retailers. Producers' share takes into account household consumption of sorghum grain as was made evident in the operating accounts. The contribution by providers of goods and services (outside of the value chain) is estimated at 32% of the total value added in the chain. However, transformers of sorghum grain – the pito and industrial brewers as well as grain processors – are by far in the lead in generating value added in the chain. Together they account for about 42% of total value added in the chain. Pito brewers' contribution of 20% of total value added is more than the contribution of the sorghum grain producers.

Figure 4.2 further confirms the dominance of transformers in terms of contribution to direct value added in the chain. This feature of the sorghum value chain contrasts sharply with the situation in most non-tradable food crops in Ghana, where very little postharvest transformation occurs prior to consumption at the household level. For example, preliminary evidence from the groundnuts value chain in Ghana shows that producers account for about 44% of direct value added, with processors only about 30%. The indication from this is that growth in the value chain may be driven more by expansion in the transformation segment than direct grain demand at the household level. This shows the potential of sorghum as an industrial crop.

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[25] *Exchange rates used in these computations are as reported by the Bank of Ghana and are: GHS 4.8 = $1.00 and GHS 5.4 = €1.00.*

[26] *Ghana Statistical Service (2019) "Rebased 2013-2018 Annual Gross Domestic Product", GSS, Accra, April 2019.*

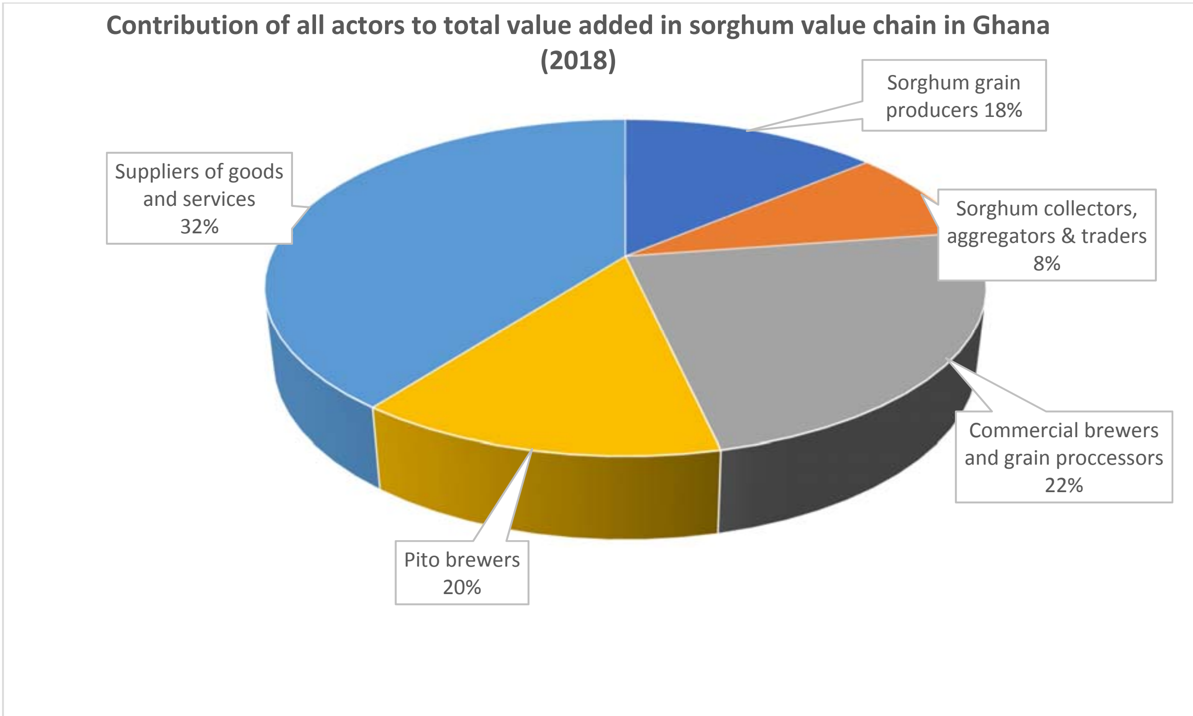

Figure 4-1: Contribution of all actors to total value added in sorghum VC in Ghana (2018)

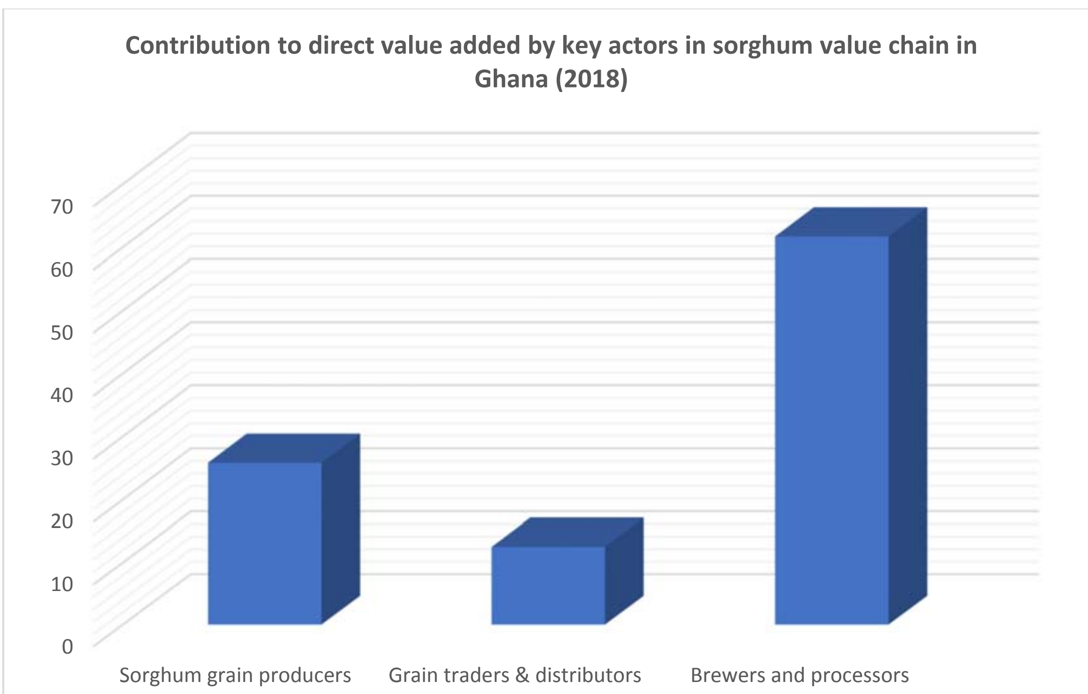

Figure 4-2: Contribution to direct value added by key actors in sorghum VC in Ghana (2018)

In Figure 4.3 depicts the contribution of different types of farmers to value added in the value chain at the level of sorghum production. It shows that by far the largest contributors, accounting for almost 60% of value added at the production level, are the SHF1 smallholder farmers. These farmers are unable to access yield-enhancing inputs even though they are entitled to subsidised inputs under the PFJ. As explained in Chapter 3, this is due largely lack of funds and it is the main reason why their productivity is very low.

The SHF2 farmers rank second in terms of contribution to value added at the level of production, accounting for about 40% of value added at that level of the chain. They are more productive than the SHF1 farmers due to support they obtain to acquire inputs, as explained in Section 4.2.1. We project that their average yield per hectare can be more than doubled if the support is scaled up to cover their needs for the of average 2.5 hectares they cultivate with sorghum (i.e. increase from 825 kilograms per hectare to about 1.8 tonnes per hectare.

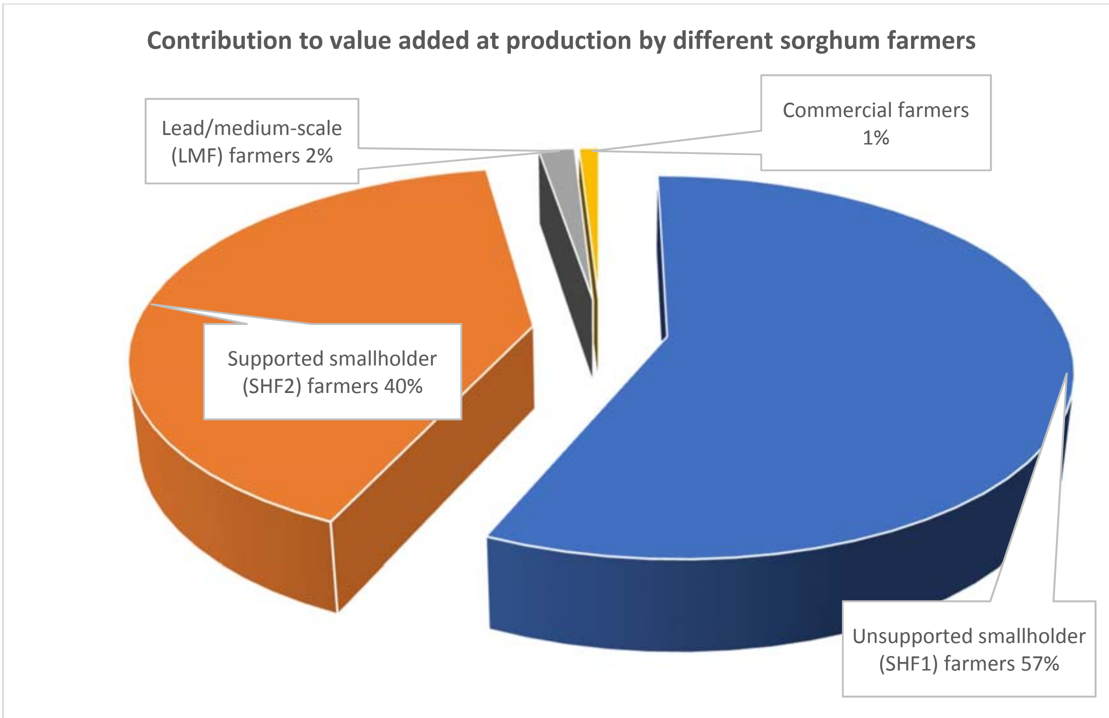

Figure 4-3: Share of value added at production by different sorghum farmers (2018)

Commercial farmers, reportedly the most productive with average yield of about 2.5 tonnes per hectare, account for only 1% of value added at the level of production. This is largely because the total area cultivated by the commercial farmers relative to overall area under sorghum cultivation is very small. The direct value added they generate through grain distribution, which involves aggregation of grains produced by SHF2 farmers, is almost double this value added at the level of production. The commercial farmers, therefore, appear to be opting for an outgrower business model centred around SHF2 farmers and supply of sorghum grain into Sub-chain 3.

Aggregators, collectors and traders (wholesalers and retailers) together contribute about 8% of total valued added in the entire sorghum value chain (see Figure 4.1). This contribution is expected to rise as Sub-chain 3 expands. This is because the spatial transformation services they offer will be complemented by other services, such as cleaning, grading, quality assurance and storage, to ensure that formal offtakers can access quality grains on a timely and consistent basis. Demand from the industrial brewery is driving growth in this sub-chain but may not be a sufficient driver unless demand by other formal offtakers is stimulated and/or scaled up.

Figure 4.4 shows the breakdown of allocation of total value added in the sorghum value chain. Income generated for actors in the value chain (i.e. their operating net profits), is by far the largest proportion of the total value added, estimated at about 37%. This is followed by the share allocated to hired labour, which accounts for about 22% of the value added This is an indication of the labour-intensity of operations at production and in the dominant downstream activity, which is pito brewing. The contribution to public finances in the form of taxes, import duties and local council levies represents a rather significant 16.3% of the value added. This is despite the fact that production does not attract taxes. This contribution is discussed further in the next sub-section.

Despite the fact that most actors in the chain have very limited access to finance, charges for financial services accounts for a significant share of the total value added in the chain, estimated at about 16%. The bulk of these charges are generated by the activities of larger-scale operators such as aggregators, grain wholesalers, the industrial brewery and service providers such as inputs distributors, transporters and tractor services providers.

Predominance of the use of basic, traditional technology in production and in downstream brewing and processing activities explains why the level depreciation is so low in the value chain. Similarly, lack of formal land rentals in the Northern Regions means there is a rather low contribution of rentals to value added – about 1%.

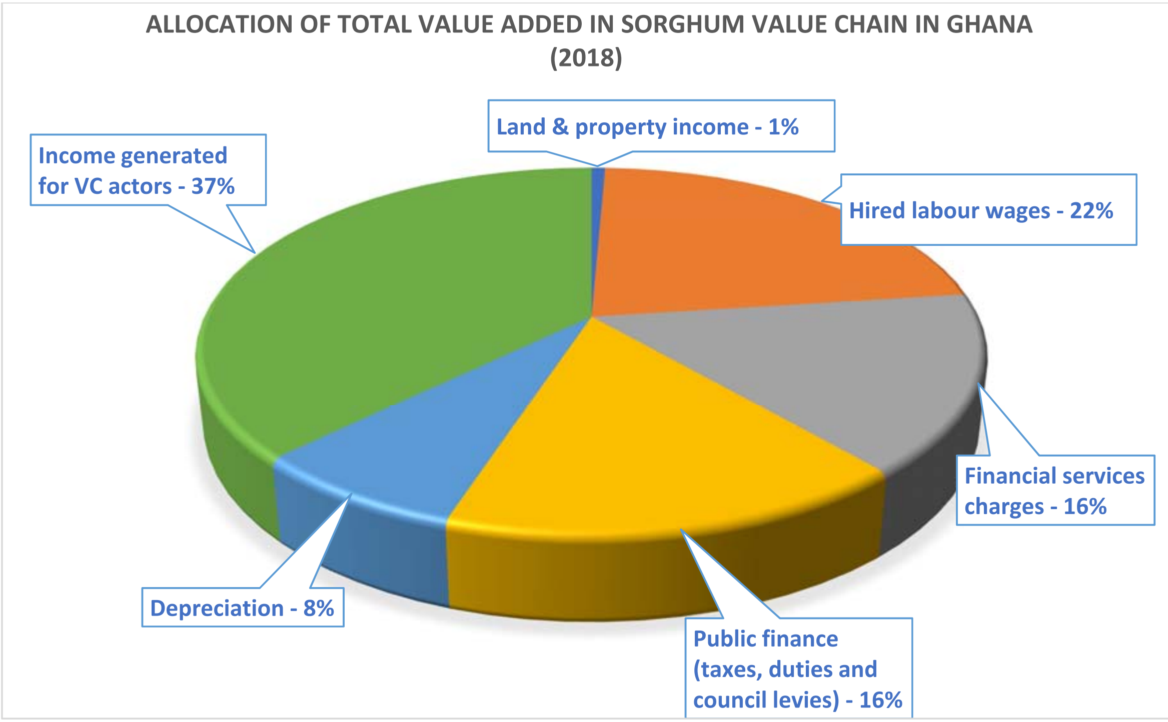

Figure 4-4: Allocation of total value added in sorghum VC in Ghana (2018)

4.3.3 Contribution of sorghum value chain to public finances

The sorghum value chain makes a net contribution to public finances in Ghana. The net contribution is estimated at GHS 159 million (i.e. $33 million or €29.4 million) per annum. The breakdown of this figure, which is reported in Table 4.6, is as follows:

- Gross tax revenues of GHS 159.14 million (i.e. $33.16 million or €29.5 million).
- Plus local council levies estimated at GHS 6.54 million (i.e. $1.36 million or €1.21 million).
- Less subsidies to players in the chain, in the form of inputs subsidies under PFJ, which is estimated at GHS 6.7 million (i.e. $1.38 million or €1.2 million).

The bulk of the tax revenue generated in the sorghum value chain (about 65%) is contributed by the commercial brewery. Suppliers of goods and other services contribute 30% of the taxes and duties, with the remaining 5% coming mainly from aggregators and wholesalers. Producers of agricultural output in Ghana, even those operating at commercial scale, are exempt from tax.

Subsidies enjoyed by the farmers represent only 4.2% of the gross tax revenues, an indication that the chain can sustain this type of support, especially if it contributes its growth and development in a manner which fosters downstream value addition as is emerging in the Sub-chain 3.

It has to be noted that SHF1 farmers are the primary target of the inputs subsidy under the PFJ. They are not only relatively poor as noted in the social analysis in the next chapter, but are also responsible for production of the bulk of sorghum grain in the country. They are also the least productive of the sorghum farmers, obtaining yields which are substantially lower than their counterparts, as noted in discussions in Chapter 3. This category of farmers could therefore have benefited the most from access to subsidised inputs under the PFJ, gaining from a boost in productivity and household earnings. However, evidence obtained during this study confirm that the SHF1 farmers are unable to access inputs for sorghum production under the PFJ due mainly to the fact that they lack the funding to pay the 50% of the cost of inputs as required under PFJ.

About 90% of inputs subsidy enjoyed by sorghum producers goes to the SHF2 farmers who are assisted by aggregators and commercial farmers to procure the available inputs. The remaining 10% of the inputs subsidy goes to medium-scale farmers, including the lead farmers, and the commercial farmers. These are better-endowed but were able to obtain their full requirements of inputs as there are no limits on the volume of inputs a farmer can acquire.

4.3.4 Contribution of sorghum value chain to balance of trade

Currently, only trace volumes of sorghum grain are reportedly exported by Ghana into regional markets. The main gain in terms of impact on balance of trade is the savings in foreign exchange which occurs as a result of replacing imported barley with sorghum grain. Our estimates, using import parity pricing, shows that the inclusion of sorghum grain as a local raw material in brewing in Ghana is resulting in foreign exchange saving of about $7.6 million (€6.6 million).

This saving is only about 18.4% of the foreign exchange currently spent on imported intermediate goods and services in the sorghum value chain. About $41.2 million (i.e. €36.7 million), is spent on imported intermediate goods and services, the bulk of which (about 44%) is utilised in importing ingredients and other inputs required by the commercial brewery.

The rate on integration of the value chain – calculated as the ratio of total value added to total chain production – is 0.78, an indication that it is well-integrated into the local economy. The value chain balance of trade – ratio of total imports to total chain production – is 15.3%. The comparative figure for the groundnuts value chain is 10.4%. At current price levels, it is difficult for Ghana to compete in the West African regional market for sorghum. This is because, whereas ex-factory gate (Kumasi) price per tonne of sorghum in 2018 was $350 (or €295) per tonne, the equivalent in Nigeria (ex-Lagos) is about $285 (or €240) per tonne[27]. Productivity gains will be important in ensuring that Ghana is price competitive vs Nigeria, especially as production in both countries is concentrated in areas with similar agro-ecological conditions.

[27] *This is based on ex-Kano market price per tonne of sorghum of Naira 84,000 ($233) and transport cost (Kano-Lagos) of $52 in 2018.*

4.3.5 Contribution of sorghum value chain to employment generation

The sorghum value chain creates about 180,000 opportunities for self-employment. This includes about 170,000 smallholder farmers as well as medium-scale farmers and about 5,000 self-employed people involved in sorghum grain distribution (collectors, aggregators and retailers). We estimate that there are over 5,500 self-employed pito brewers. In addition, the pito brewing industry employs about 15,000 low-wage workers, almost all women who also take advantage of the employment to accumulate start-up equity for their own pito brewing enterprises. Based on the average wage per day of about GHS 10 and the expenditure on hired labour, we estimate that about 50,000 "by-day" labourers are engaged in sorghum production and harvesting in the course of a season. Most of them are employed by SHF2 farmers, LMFs and commercial farmers. The income per season, which ranges between GHS 720 (i.e. $135 or €120) and GHS 1,320 (i.e. $245 or €215) is significant in terms of household income in rural communities.

The emergence of Sub-chain 3, due in part to the commitment by the industrial brewery to increase local raw material content in commercial brewing, is triggering an increase in the number of relatively more stable and better-remunerated jobs in the sorghum value chain. For instance, based on the hired labour costs, we project that about permanent 400 jobs may have been created in the operations of the aggregators and commercial farmers at wage levels of about two times the national minimum wage. It is also projected that within the services supporting the sorghum value chain, there are over 14,500 relatively low-wage jobs.

4.3.6 Assessment of sustainability of sorghum value chain

One means of assessing the viability of the sorghum chain within the global economy is by computing the domestic resource cost (DRC) ratio. The DRC is calculated by dividing the sum of labour and capital costs valued at social costs (free of distortions in these markets), by the difference between production and transferable inputs also at social costs (FOB prices). So DRC = (A+B)/(C-D) if:

- A: labour costs at social prices
- B: capital costs at social prices
- C: production value at social prices

D: transferable inputs at social prices Based on the data reported in Tables 4.4 to 4.6, the DRC for the sorghum value chain in Ghana is estimated at 0.35, which is well below unity (i.e. <1). The implication is that the value chain has a comparative advantage and is viable within the global economy. DRC also measures the overall economic gain or loss for the national economy and at the low end, as is the case in sorghum, indicates high social benefits to the national economy.

We calculated the nominal protection coefficient (NPC) by dividing value of production at market gate by production at international price, using import parity price for sorghum delivered from Nigeria, which is close to the Ghanaian border and, in principle, can export without restrictions into the local market. Whilst current ex-warehouse price offered by the industrial brewery is GHS 1,900 per tonne of sorghum grain, the import parity price (ex-Tema) is estimated at GHS 1,725.

The NPC is therefore estimated at 1.10 – indicating some protection for the local sorghum producer, highlighting the need for productivity gains which will enhance price competitiveness, especially within the ECOWAS regional market.

4.3.7 Assessment of inclusiveness in the sorghum value chain

As reported above (in Figure 4.4), about 37% of total value added accrues to actors in the chain. Distribution of the income generated in the value chain is depicted in Figure 4.5, which shows that about 75.4% of this income accumulates to main actors in the chain. The share of the income which is obtained by suppliers of goods and services is 24.6%.

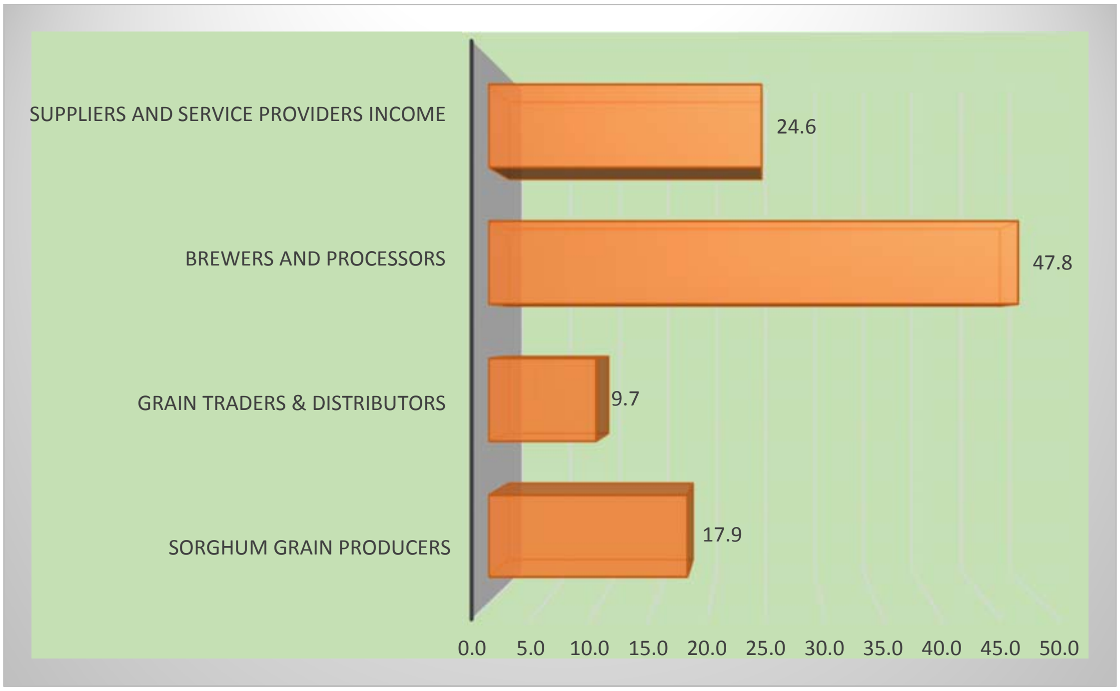

Figure 4-5: Distribution of actors' income in Ghana's sorghum VC (2018)

The sorghum value chain is evidently inclusive as demonstrated by the distribution of income accruing to key actors in the chain in Figure 4.6 below (i.e. excluding the suppliers of goods and services). Most of the income generated in the chain, about 79%, accrues to small and micro-scale actors. The share of income generated which is due to smallholder producers is about 23%, which is higher than the 21% generated by all the large-scale actors such as commercial brewery, large-scale aggregators and large-scale grain wholesalers. Indeed, income generated by the pito brewers alone is about 49%. It is noteworthy that this activity is almost exclusively undertaken by women, who are also well-represented at the level of sorghum grain production.

As reported in Table 4.6 above, total wage income generated in the value chain is estimated at just over GHS 226 million (i.e. $47 million or almost €45 million). About 41% of this is paid by suppliers and service providers to their workers. The distribution of wage income for the key actors in the value chain is shown in Figure 4.7 below and further illustrates inclusiveness in the value chain. The figure shows that workers' wages paid by the main actors in the sorghum value chain is concentrated at levels in the chain currently dominated by small/medium-scale actors. In particular, pito brewers and smallholder farmers (both SHF1 and SHF2) are the main source of wage labour income in the chain. Together, these actors account for a total of 91.7% of the wage labour income provided by the direct actors in the chain (i.e. excluding the suppliers and service providers).

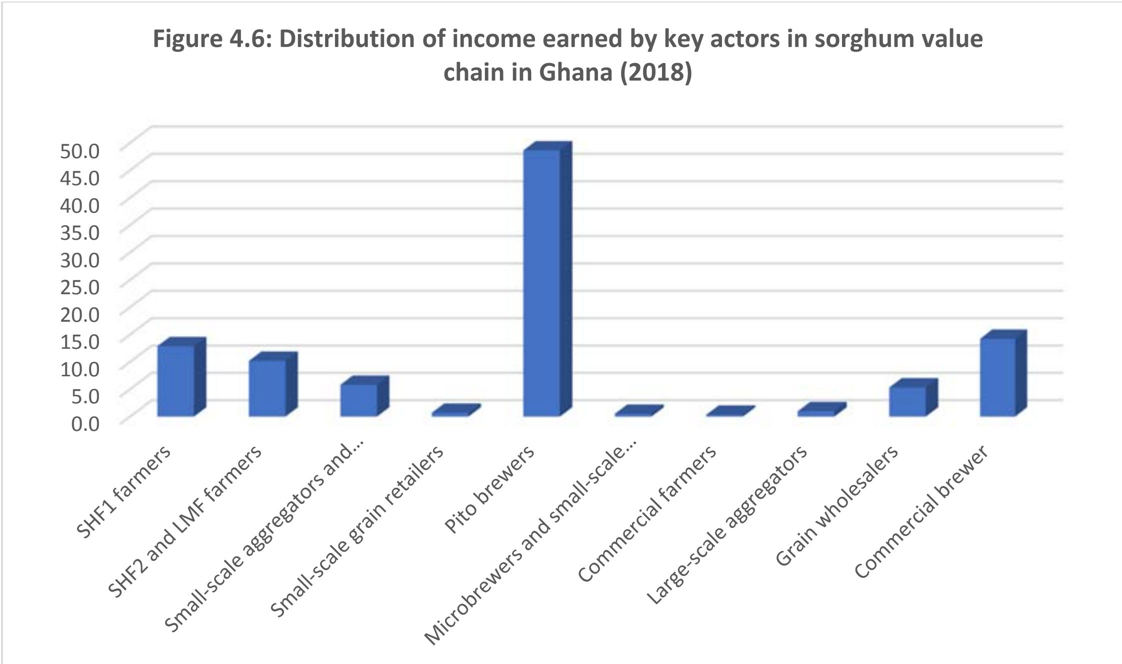

Figure 4-6: Distribution of income earned by key actors in sorghum VC in Ghana (2018)

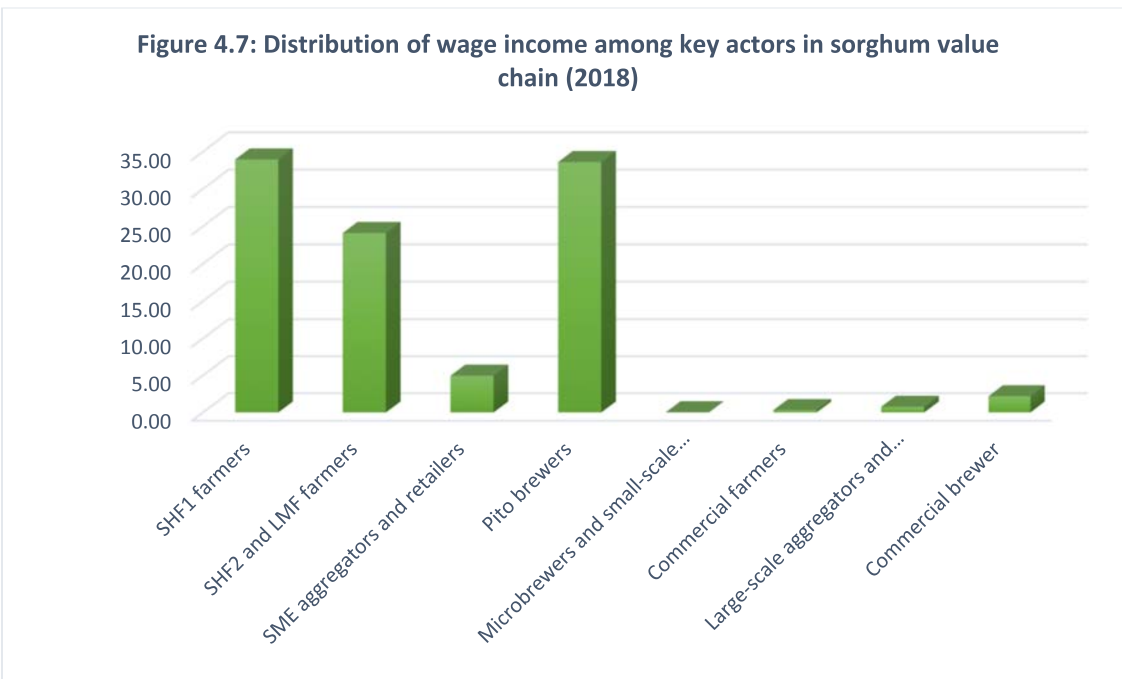

Figure 4-7: Distribution of wage income among key actors in sorghum VC (2018)

4.4 Conclusions from economic analysis

Evidence from the economic analysis undertaken in this chapter is summarised in Table 4.7 below. The financial analysis shows that the operations of all the key actors in the sorghum value chain are profitable. This includes sorghum production by the low-input, low-productivity smallholder farmers (categorised in this report as SHF1). The average return on turnover obtained at this level of operation is about 22.3%, but the earnings are rather low and not able to sustain a family if it entirely subsists on it. Sorghum-based annual income generated by SHF1s is estimated at GHS 215 (equivalent to $45 or €40) per farmer. Assuming the farm household cultivated only sorghum rather than the current allocation of only 30% of cultivated land to the crop, the projected annual income will be about GHS 715 ($149 or €132) which is about 45% below the national poverty line, estimated at GHS 1,315 per annum.

The emergent smallholder farmers (SHF2), with average return on turnover of 24.2%, also generate significantly higher household incomes from sorghum production – about GHS 620 ($129 or €115) from allocating 40% of area planted to the crop. Assuming they committed 100% of their farm land to sorghum their average annual income rises to an estimated GHS 1,540 ($322 or €287), which is above the national poverty line but below annual minimum earnings from wage labour (about GHS 3,065 or $640 or €565). The SHF2 farmers receive support from large-scale aggregators and commercial farmers to acquire and utilise inputs (mainly fertiliser and pesticides) as well as ploughing services but the support covers only 20% of their requirements. The aggregators and commercial farmers running such schemes usually rely financing from sources such as the OVCF and the MOAP-supported Revolving Fund (see Box 3.1). As a result the SHF2 farmers obtain higher yields, are able to expand area under sorghum cultivation and to to supply into the emerging formal marketing chain for sorghum (in sub-chain 3).

The better-endowed lead and medium-scale farmers (LMF) and commercial farmers obtain not only attractive average returns but also their farm incomes are well above the national living incomes. It is apparent that securing funding to acquire inputs which are available under the government's PFJ is critical in successfully making the transition from the low-input, low-productivity and low income sorghum farming practiced by the SHF1 farmers.

Though margins in the distribution segment of the value chain are much tighter than at the production level, the incomes generated are high and encourage entrepreneurs to invest in grain distribution, either as specialised activities or as a major part of commercial farming operations. Margins and average annual incomes for brewers and processors also average above 16%. Pito brewers for instance can earn about GHS 25,300 (i.e. about $5,260 or €4,680) per annum, which is more than double the national living wage. Sorghum grain processing is also lucrative but upscaling appears to be hampered by challenges in complying with licensing requirements for setting up the processing units and for licensing products for the market.

Total value added in the sorghum value chain in 2018 is estimated at GHS 1,016 million, which is equivalent to almost US$211.2 million or €188 million. This includes direct value added estimated at GHS 689.1 million (i.e. $143.3 million or €127.6 million) indirect value added amounting to about GHS 326.97 million (i.e. close to $68 million or €60.6 million). The total value added is close to 2.0% of the overall agricultural GDP in Ghana.

A breakdown of the contributions to value added by different categories of actors in the chain is as follows:

- Grain producers – 18% (more than double the contribution from players in the distribution chain such as rural collectors, aggregators, wholesalers and retailers) who contribute 8%.
- The bulk of the value added in the chain, about 42% is generated by grain transformers such as pito brewers, industrial brewers and grain processors.
- Suppliers and service providers contribute about 32% of the total value added in the chain.

The net contribution of the sorghum value chain to public finances in Ghana is about GHS 159 million (i.e. $33 million or €29.4 million) per annum per annum. This figure is net of the inputs subsidies under PFJ, which is estimated at GHS 6.7 million. The subsidies represent only 4% of the gross tax revenues from the value chain. It must be noted, however, that the poorest category of farmers, the SHF1, are not benefiting from the subsidy due to their inability to raise funds on their own to pay the remaining 50% of the cost of the inputs.

Currently, only trace volumes of sorghum grain are reportedly exported by Ghana into regional markets. About $41.2 million (i.e. €36.7 million), is spent on imported intermediate goods and services within the chain. The use of sorghum grain as a local raw material in brewing is saving about $7.6 million (€6.6 million).

The sorghum VC creates about 180,000 opportunities for self-employment, including smallholder farmers as well as those engaged in sorghum grain distribution (collectors, aggregators and retailers). There are also over 5,500 self-employed pito brewers, an industry which employs about 15,000 low-wage workers, almost all women, who also take advantage of the employment to accumulate start-up equity for their own pito brewing enterprises. There is evidence that new low-wage, temporary ("by-day") labour employment opportunities have emerged along with more permanent and better-remunerated jobs have been created as a result of commercial sorghum cultivation and grain aggregation.

The value chain is well-integrated into the local economy as shown by its estimated rate of integration of 78%. The domestic resource cost (DRC) ratio in the chain is also estimated at 0.35, which is well below unity (i.e. <1) and indicates that the value chain has a comparative advantage and is viable within the global economy. The nominal protection coefficient is 1.1, an indication that players in the chain currently enjoy a certain level of protection. The value chain is also highly inclusive as evidence generated through this study shows that most of the income generated in the chain accrues to small and micro-scale actors including smallholder producers (especially the SHF2), small/micro-scale grain collectors and retailers as well as pito brewers.

Table 4-7: Summary of evidence from economic analysis of sorghum value chain in Ghana

Framing Question 1: What is the contribution of the VC to economic growth?		**INDICATORS**	**RESULTS**
CQ1.1	How profitable and sustainable are the VC activities for the entities involved?	**Profitability measure (return on turnover)**	**Farmers:** • **SHF1** – 23%; **SHF2** – 24.2%; **LMF** – 18.9%; and **CF** – 48.1%.
		Benchmarks of farmers' net income per annum with minimum wage and/or job opportunities:	- National Poverty line = GHS 1,315 ($275 or €245) - National minimum wage = GHS 3,065 ($640 or €565) - National Living Wage = GHS 10,000 (or $2,085 or €1,850)
		Net income by type of actor	**SHF1:** Current at 30% area planted = GHS 215 ($45 or €40); or at 100% = GHS 715 ($148 or €132). **SHF2:** Current at 40% area planted = GHS 620 ($129 or €115); or at 100% = GHS 1,545 ($322 or €287). **LMF:** Current at 60% = GHS 2,640 ($550 or €490); or GHS 4,400 ($915 or €815) at 100%. **Rural collectors:** GHS 4,830 ($1,000 or €900) **Small/medium-scale aggregators:** GHS 14,320 ($2,975 or €2,650) **Retailers:** GHS 1,345 ($280 or €250)* sells other cereals.
Framing Question 1: What is the contribution of the VC to economic growth?		**INDICATORS**	**RESULTS**
CQ1.2	What is the contribution of the VC to the GDP?	**Total VA and components**	**Total VA = GHS 1,016 billion** **Components:** Land/property income = 0.7%; Wages = 22%; Financial charges = 16.0%; Public finance = 16.3%; depreciation = 8%; and actors' net income = 37%
		VA share of the GDP	**Total VA share of GDP = 0.3%**
		Rate of integration into the Economy (total VA/VC production)	**Total VC production = GHS 1.297 billion** **Rate of integration = 0.78**

CQ1.3	What is the contribution of the VC to the agriculture sector GDP?	**VA share of the Agriculture sector GDP**	**Share of agriculture GDP = 1.85%**
CQ1.4	What is the contribution of the VC to the public finances?	**Public Funds Balance**	**Gross contribution** (taxes/duties & local council levies) = GHS 165.7 million; **Less Inputs subsidy** = GHS 6.7 million; Net contribution = GHS 159 million
CQ1.5	What is the contribution of the VC to the balance of trade?	**VC Balance of trade**	**VC imports = GHS 198.24 million ($41.2 million); savings from substituting imported barley with sorghum grain ($7.6 million)**
		Total imports / VC production	**15.3%**
Framing Question 1: What is the contribution of the VC to economic growth?		**INDICATORS**	**RESULTS**
CQ1.6	Is the VC viable in the international economy?	**Nominal Protection Coefficient (NPC)**	**1.10** (indication of a level of protection)
		Domestic Resource Cost Ratio (DRC)	**0.35** (indicating VC has comparative advantage)
Framing Question 2: Is this economic growth inclusive? *(To be completed with Social Analysis results)*		**INDICATORS**	**RESULTS**
CQ2.1	How is income distributed across actors of the VC?	**Total farm income**	**GHS 67.94 million**
		% final price at farm gate	**In Sub-chains 1 and 2 = 50.2%; and 68.4% in Sub-chain 3.**
		Total wages and salaries	**GHS 226.13 million**
CQ2.2	What is the impact of the governance systems on income distribution?	**Income distribution**	**Sub-chain 3:** involves hierarchical control by a dominant buyer and strict enforcement of commodity standards. However, compliance capacity appears to have been built so there is significant smallholder participation. Contract-based pricing allows for higher share of farmers in final grain price, as indicated above. **Sub-chains 1 and 2:** channel rather informal, lacks enforced standards for quality and measures, making trade rather opaque; farmers' share lower but also compensated by share received by rural collectors.
CQ2.3	How is employment distributed across the VC?	**Number of jobs and self-employment**	**Self-employment estimated at over 180,000** (at level of production, trading and processing – including pito brewing).

			Informal low-paid temporary (by-day) jobs likely to exceed 100,000; formal more, permanent and more remunerative jobs emerging around commercial farms and formal grain aggregation into Sub-chain 3.

5 SOCIAL ANALYSIS OF SORGHUM VALUE CHAIN

5.1 Introduction:

The social profile covers six themes: 1) working conditions, 2) right and access to water and land, 3) gender equality, 4) food and nutrition security, 5) social capital and 6) living conditions. The social profile breaks down the 6 domains into 22 subsets and 63 questions for analysis and scoring. The social profile is based on a spreadsheet and formula in an excel table (see Appendix 4) which includes recommendations on each risk identified as well as Figure 5.15 for the spiderweb with aggregate outcome of the scores on the six dimensions. The two framing questions under the social analysis are:

- Is the economic growth inclusive?
- Is the value chain socially sustainable?

The methodology used in study is outlined in Section 1.2 of this report. It involves a mixed methods design including literature review, stakeholder interviews and focus group discussions (FGDs) to complete the social analysis. The outcome of the analysis is reported in this chapter as follows: Section 5.2 elaborates on the results of analysis related to six domains of the social analysis. In Section 5.3 a summary of the social profile of actors in the value chain is provided, including a visual representation in the form of a spider web. The summary includes the main issues and challenges facing the main sorghum VC actors. Section 5.4 contains the concluding remarks and some practical recommendations.

Sorghum sub-chain specifics

Consistent with the boundaries set for analysis in this study in Section 1.3.3, the social analysis covers all actors in all the sub-chains. It is evident that issues affecting the actors, especially at the level of production are very similar in both Sub-chains 1 and 2. This is because production in the two sub-chains is dominated by smallholder farmers. The only distinction is that SHF1 farmers in Sub-chain 1 are unable to utilize yield-enhancing inputs whilst the SHF2 farmers, who operate in Sub-chain 2 are able to do so due to the support they receive from large-scale aggregators as well as commercial farmers to whom they are linked. For instance, the findings for the areas of food and nutrition security, social capital and livelihoods have similarities for the actors of both sub-chains.

The structure of the grain trading systems and their governance also differ as discussed in Section 3.5. One impact of this situation is that SHF1 farmers generally obtain farmgate price for sorghum which is about 20% lower than SHF2 farmers. This is discussed in the results of analysis of producer margins in Section 4.2.1. It is not only such nuances which are important but the team notes that the bulk of the sorghum grain produced in Ghana is from Sub-chain 1. The crop is also relatively more important in household food security than for the players in the other Sub-chains.

In terms of the social analysis, one of the main distinctions which emerge between Sub-chain 3 and the other sub-chains, is working conditions. The results which emerge from the analysis are rather unique to the industrial brewery and commercial farmers who are both in Sub-chain 3. A specific and important group of actors in Sub-chain 2 are the urban pito brewers, not only because of their contribution to value added in the value chain but also the gender which dominates that activity. Each sub-question of the social analysis distinguishes between the sub-chains and actors where applicable and relevant.

5.2 Main findings from the six domains of social inquiry:

5.2.1 Working conditions

Social acceptability and sustainability of working conditions are analysed in terms of labour rights, child labour, work safety and attractiveness. Are working conditions throughout the VC socially acceptable and sustainable? This is the key guiding question of this section. We distinguish between the following main VC actors: i) sorghum producers, ii) labourers of commercial sorghum producers, ii) pito brewers, iii) workers at the industrial brewery and iv) other smaller categories like transporters, carriers, traders and retailers.

Formal respect of labour rights but lack of control in the rural areas and at commercial sorghum farms:
In analysing the respect of labour rights we focus on the workers at the industrial brewery which has a considerable workforce. Other workers at various VC stages and product flows are staff of service providers, of aggregators including transporters and carriers, of larger producers of sorghum and seed (including harvesting, cleaning and sorting). The Ghana Government, Ministry of Labour, adheres to the 8 ILO conventions[28] and checks for compliance with. However, there is no monitoring and control of compliance by the Ministry of Labour in the agricultural sectors. According to the ministry, the main issues reported on violation of the conventions do not apply to the sorghum VC and the companies involved. The issues and workforce related problems occur in the cocoa VC and in the mining industry.

According to the country's Ministry of Employment and Labour Relations, Ghana's national daily minimum wage is to increase per January 1, 2020 by 11% to GHS 11.82 (U.S. $2.16) for 2020, up from GHS 10.65 (U.S. $1.94) for 2019. Employers that do not fulfil their obligation to pay the minimum wage are subject to penalties, the commission said. However, we learnt that there is rare official monitoring and control of farm wage labour which means that it is quite easy for employers, e.g. commercial farmers employing labourers, to bypass the official rule of law. When in the field, we recorded non-compliance of the minimum wage among wage labourers of commercial farmers. One labourer interviewed was paid GHS 7 daily. Also the majority of employment in the VC is on casual and informal basis and often paid per output (e.g. acre harvested or bag sorted) rather than as a daily wage. This practice makes it also easy to pay less than the minimum daily wage. Harvesting is often done by rotation and in groups. The group of workers employed to harvest get – on average – an amount of GHS 50 per acre (lunch and drinking water included, GHS 70 without lunch and drinking water provision). The group varies from 7-12 persons. A group of 10 people can harvest three (3) acres a day, that means that a group of 10 persons receive GHS 150 daily which is GHS 15 per person per day.

Freedom of association is formally allowed in Ghana. However, collective bargaining appears to occur only at the level of the industrial brewery but is not common at other enterprises.

Unfortunately, we could not access some information on work force at the industrial brewery, including age, gender and background of the workers as well as their wages and secondary benefits. Also it was not possible to conduct a survey of the staff of the industrial brewery for their opinion on working conditions and job satisfaction. However, based on our observations and the information we obtained we can conclude the following. ***Working conditions at the industrial brewery reason for optimism***
The ILO standards are respected by the industrial brewery. The workers are organised and have a voice. They all have formal and written contracts. The wages offered appear to be competitive relative to similar organisations in the country and secondary benefits increases the fairness of contracts. An important secondary benefit is access to health care for the employee and first grade family members. . Gender balance is very important, and is a serious target. Women have crucial management positions and Health and Safety Standards and Control are very important at the company. Strict measures related to these as well as facilities and materials are in place. There is awareness among workers and risk mitigations measures are in place.

Child Labour does not occur in the sorghum value chain
Forced labour and child labour does not seem to occur in the sorghum VC in Ghana. The main issues and problems around child labour occur in cocoa, mining and fishing. However, as soon as sorghum becomes profitable and is perceived as a cash crop, there could be a risk for children to be involved in the value chain and to use them as a cheap labour force. Especially children in the rural areas are a risk group when primary or secondary schools are not accessible or when parents or family members cannot afford school fees. The industrial brewery which is active

[28] Forced Labour Convention, Right to Organise and Collective Bargaining Convention, Equal Remuneration Convention, Abolition of Forced Labour Convention, Discrimination (Employment and Occupation) Convention, Minimum Age Convention and Worst Forms of Child Labour Convention.

in the sorghum value chain usually conducts assessments and checks on use of child labour by firms and commercial farms which are contracted to supply grains to it.

Job safety is prioritised at the formal brewery but is a challenge at the pito brewing

Generally, health and safety risks seem relatively low in the sorghum VC. At production stage health risks seem minimal and pesticides are hardly applied in sorghum production. However, working conditions in the field for farm labourers can be risky as there is the danger of snakes and bugs and we noticed first aid kits are not always available or nearby. Also working in the open fields being subject to all weather circumstances can be tough. We did notice that drinking water and sometimes lunch is provided for the farm wage labourers. The post-harvest labour conditions seems not very favourable for the mainly women workers, sitting on the ground floor for hours (Figure 5.1). Temporary workers involved loading offloading grains into storage for aggregators, at the brewery and during transportation are similarly vulnerable.

Figure 5-1: Women sorting sorghum seed in Upper West Region, Ghana
Source: C. Plaisier (May 2019)

The local pito brewing process is hazardous and can cause serious health problems because of the smoke and heat from the open fire (see Figure 3.4). Among the actors it seems awareness or recognition of the potential harm is rather low. This is in sharp contrast with the situation in the industrial brewery, where awareness of risks is high, safety measures are instituted and enforced (Figure 5.3). The team noted that there is available, rather simple, low-cost technology which can significantly reduce the identified risks in traditional pito brewing (Figure 5.2) and also reduce energy cost for the brewers (discussed in Chapter 7 of this report).

Figure 5-2: Traditional pito brewery place in Wa: before and after new burner (C. Plaisier, May 2019)

Figure 5-3: Security and Safety at the industrial brewery Kumasi
Source: C. Plaisier (May 2019)

High attractiveness of sorghum but still below potential
Overall, from the perspective of all VC actors, sorghum is considered an attractive value chain, which offers income-generating job creating opportunities along the entire chain. This perception is confirmed in the economic analysis reported in Chapter 4. For instance, pito brewing seems to provide for a continuous stable source of income and is profitable for the pito brewers. Wages and secondary benefits at the industrial brewery are very attractive compared to other sectors. Though commercial farmers find investment in the value chain attractive, it is apparent that they face a major challenge in attracting farm workers and the consequent shortage of labour, especially during the

harvest season. Generally, the farm workers have their own fields and are not able to commit themselves full time during the agricultural peak seasons and there is also a lack of higher educated skilled labour. From the labour supply perspective, people, especially youth, do not find it very attractive to work as a farm wage labourer. In response, the commercial farmers appear to favour outgrower schemes where they support SHF2 farmers to obtain inputs and to supply sorghum grain.

The survey shows that sorghum is very important for all categories from producer to trader. We asked the respondents to indicate the importance in terms of income of sorghum for them on a scale from 1-10 with 10 being very important. The average given is 8.2 which means that sorghum is very important and 54% indicates that sorghum is very important as a source of income (Figure 5.4). But when we asked the respondents if they would like their child(ren) to become active in sorghum, only 59% would like their children to be active in sorghum with the main reason given is that sorghum is profitable. About 37% would like to see their children to have other sources of income. The reasons given vary. One argument is that if their children attend school they would have other – better opportunities in the future after graduation.

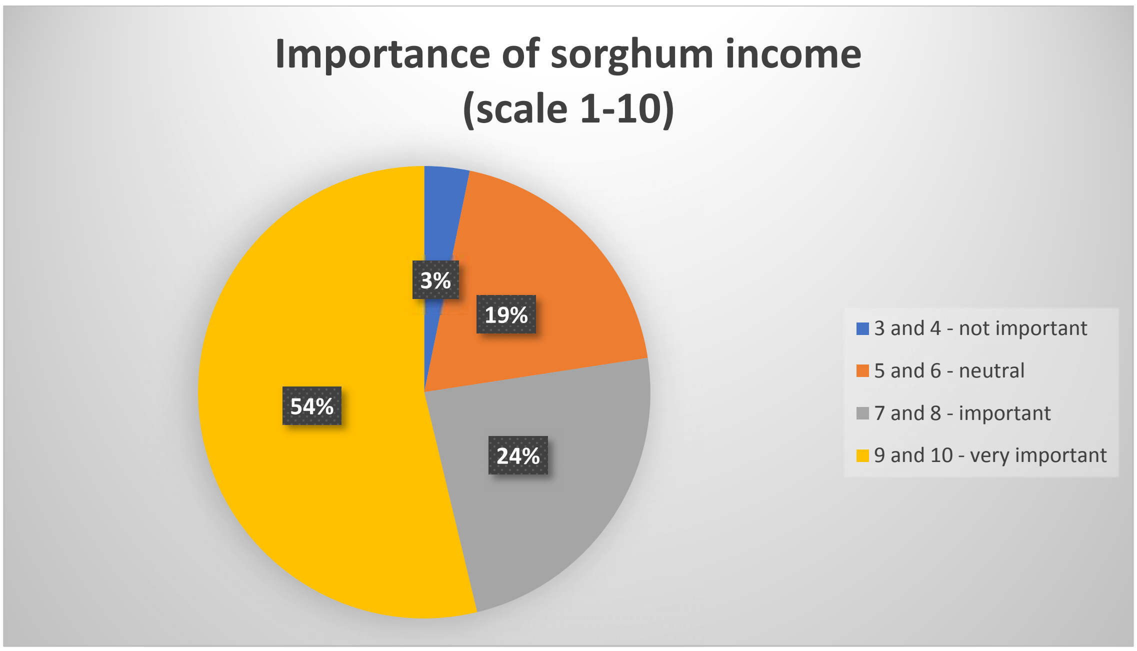

Figure 5-4: Importance of sorghum income, source survey sorghum actors, September 2019
Source: Authors

The Individual Living Wage in Ghana is not known for 2019 but was 900 GHS/Month in 2018 and 860 GHS/Month in 2017. With a wage job at the minimum daily wage with six days work week and four weeks a month, the total wage income would be GHS 255.60 only which is not even a third of the Living Wage of 2018. This indicates that the current income from wage labour in sorghum cannot provide for a decent standard of living. It explains why most of the farm workers retain their own farms.

Youth and sorghum: attractive and offers opportunities

Partly as a result of the involvement of the industrial brewery, sorghum is being increasingly perceived as cash crop among the youth. During the Focus group discussionss, some of the youth who participated mentioned that a ready alternative is involvement in artisanal mining, which promises high returns but is also perceived as highly risky. The youth also perceive sorghum cultivation as relatively low labour-intensive because of the possibility of mechanical ploughing as well as use of herbicides for weed control. The challenge, however, is that of securing financing support from an aggregator or commercial farmer. In addition, several youth employment opportunities have been created as a result of the emergence of a formal grain market centred around procurement by the industrial brewery. The aggregation and storage companies, input providers, tractor service providers, mechanicals, seed breeding, and the formal breweries are attractive workplaces and opportunities for youth. We met several young people at all stages in the sorghum chain including the input (seed breeding), production stage, aggregation and breweries.

Access to credit is challenging for all value chain actors and hampers start-ups, investments and growth. Banks not only require a reliable track record which is impossible for start-ups and youth but they also require collateral (e.g. land). This is a serious constraint for youth in a business start-up or for expansion of current operations.

5.2.2 Land and water rights

Socially acceptability and sustainability of land and water rights are analysed in terms of responsible governance according to the UN Land Regimes. Are land and water rights socially acceptable and sustainable? This is the key guiding question of this section. The theme is divided into three sub-themes, namely: Accession to the Voluntary Guidelines for the Responsible Governance of the UN Land Regimes (2012)[29], Transparency, participation and consultation, and Equity, compensation and justice. In the context of the sorghum VC in Ghana, this mostly relates to land rights, land transfers, management of climate change and management of natural disasters.

The vast majority of land is held informally under customary tenure, while approximately 20% of land in Ghana is officially owned by the state.

In 2003, Ghana launched a major land reform project aimed at improving land registration, institutional capacity building, land dispute resolution and the harmonization of statutory and customary systems governing land. Under the country's mixed system of English common law and customary law, land is governed under overlapping customary and formal land rights regimes. The vast majority of land is held informally under customary tenure, while approximately 20% of land in Ghana is officially owned by the state. In recent years, tensions and conflicts over land have been exacerbated by the expansion of mining and bio fuel cultivation. While women have legal rights to own and inherit property, in practice under customary law their rights are greatly restricted and they themselves do not own land. The main issues on land in Ghana are tensions between customary and formal land rights regimes; pastoralists' rights; women's land rights; legal protections associated with compulsory land acquisitions and insecurity of rural people's land rights (LandPortal 2019).

Adherence to the Voluntary Guidelines on Responsible Governance of Tenure: low awareness

The purpose of the Voluntary Guidelines on the Responsible Governance of Tenure (VGGT) is to provide guidance to improve the governance of tenure of land, fisheries and forests with "*the overarching goal of achieving food security for all and to support the progressive realization of the right to adequate food in the context of national food security*". Adherence to VGGT is analysed in terms of position of smallholders and land acquisition. Although Ghana adopted the VGGT, The district office of the Land Commission in Wa is not aware of the VGGT and no information is available from the national office of the Land Commission in Accra. USAID, FAO, International Land Coalition (ILC), Land Policy Initiative (LPI) and many other donors and organizations continue to work with governments and at country-level to ensure that the VGGT are implemented. But according to many actors on the ground the concerned actors do not integrate the guidelines systematically into their safeguards, land programmes, company policy and national laws (ActionAid 2019). ActionAid also identifies the lack of resources and implementation capacities as a shortcoming of the VGGT that needs to be addressed. Effective implementation of the VGGT as a whole, requires gender-responsive approaches that place an emphasis on financing as well.

Land expropriations: not in sorghum

Delayed payments of compensation for compulsory acquired lands by the state have been cited as a major cause of land litigation and inadequate security of tenure in the country but as far as we know at this stage, these cases are not related to sorghum VC. Smallholders are still predominant in the sorghum sector and no recent cases of land expropriations are known in the sorghum VC. The main issue concerning land in the sorghum VC in Ghana relate to: a) the traditional system of land ownership and b) exclusion of women. Approximately 80% of the land is owned by traditional authorities (chiefs) while government owns only 20%.

Sorghum smallholders generally do not have land title, limits access to credit and expansion of cultivation.

Allowing requests for cultivation of land owned by traditional authorities very much depend on your personal

[29] The VGGT, internationally negotiated under the United Nations (UN) Food and Agriculture Organization (FAO) over a nine-month period, involving 96 member countries and over 30 civil society organizations, were adopted by the Committee on World Food Security (CFS) in May 2012.

relationship and family name. So it is very subjective whether a person has the possibility to access and expand land for (temporary) cultivation. There is discrimination of women as they in general can only access land via their spouse or a male relative. Another factor contributing to complexity and difficulty in land titles is the lack of collaboration and alignment between the traditional authorities and the state system. Usually it is impossible to buy land, but if you are allowed to purchase lands from the traditional authorities, all its registration and titling is done by the state system but they do not effectively work together which results in land litigations and tenure insecurities.

Transparency, participation and consultation: traditional decision making system in place.

Without examples of recent large scale land purchase in the sorghum sector in Ghana, this study was not able to go into detail of the process and level of engagement and consultation. We assume though that the information provision (transparency), participation and consultation of local stakeholders is high in the sense that the chiefs have the final say and decision power on the allocation of land, but it is very low in the sense that only the chiefs can decide. Decision making is based on a traditional local system which overrules the formal rules and regulations.

Equity, compensation and justice: The locally applied rules do not promote secure and equitable tenure rights or access to land and water

There are many producers, especially smallholders, who do not have a land title. The process of formalising land titles is very long and complicated and many farmers do not want to start the process which is perceived as never ending. Lack of property rights is however not seen as major challenge by the sorghum value chain actors, but it does limit access to credit and expansion of cultivation. The traditional system where land is decided upon by the village/community chief is still up and running. It very much depends on your personal relationship and family name whether you will have the possibility to access land for temporary cultivation. It is very difficult to acquire a land title, especially for women and youth (see also Gender section).

Formal system in place for ensuring fair and prompt compensation but enforcement, transparency and control can be doubted

No recent cases of land expropriations are known in the sorghum sector. The commercial farmers contracted by the industrial brewery are subjected to assessments. If the government is the expropriator, they have to adhere to the compensation rules which are in place. The sad situation is that it is very tempting for smallholder family members who own land to sell it a very low price: they get immediate cash and a huge amount of money at once. This is very attractive at the short term but many reported to regret their land sales in the long run. It seems there is no information system or 'warnings' from respected and influential sources in place to protect people to sell their land. "Outsiders' can either buy family own land or ask for permission to the local chief to cultivate land.

Livelihoods are disrupted by climate change and no alternative strategies are considered or in place

Climate change has consequences for the sorghum producers as weather becomes very unpredictable. Ghana has experienced climate changes; droughts, floods and erratic weather conditions continue to threaten the livelihoods of people in Ghana especially in the northern regions (sorghum producing areas). Many producers feel unable to adapt to climate change or cope with natural disasters. Insufficient measures seem to be in place to cope with climate change and natural disasters. The increased temperature, erratic and unpredictable rainfall and drought like conditions could affect sorghum production. Most agricultural production (including sorghum) in Ghana relies on small, rainfed plots that are highly vulnerable to the impacts of climate change (Meteo Institute 2019). According to various reports and literature and data of the Meteo Institute in Ghana, Ghana has experienced climate changes; droughts, floods and erratic weather conditions continue to threaten the livelihoods of people in Ghana especially in the northern regions. The main stressors are (USAID 2017):

- Rising temperatures
- Reduced rainfall, change in distribution (very erratic and unpredictable)
- Drought-like conditions

The first three stressors (temperature, rainfall and drought like conditions) could affect sorghum production as well. Most agricultural production (including sorghum) in Ghana relies on small, rainfed plots that are highly vulnerable to the impacts of climate change (USAID 2019, www.rainwatch-africa.org, Meteo Institute 2019). Erratic precipitation patterns have severe consequences on production, as only 2% of the country’s irrigation potential has been tapped. Rising temperatures are projected to lower yields in major staple crops (cassava, yams, plantains, maize and rice).

Cassava yields, for example, are projected to fall by 29.6% by 2080 and maize yields by 7% by 2050. Total crop failure is expected to occur approximately once every five years in Ghana's northern region due to delayed or diminished rains. Cocoa, a major cash crop and Ghana's second leading foreign exchange earner, is sensitive to rising temperatures and drought. Areas suitable for cocoa production, which lie primarily along the coast, are contracting as temperatures rise, floods increase, and soil salinization and coastal erosion continue. USAID identifies the main risks as a consequence of the stressors in agriculture:

- Increased crop loss/failure and reduced yields, particularly for cassava (not yet known for sorghum);
- Increased incidence of pests and crop diseases;
- Shorter growing seasons;
- Desertification and loss of arable land for agricultural production;
- Soil salinization and saltwater intrusion into coastal aquifers.

What should get attention in sorghum farming related to climate change and climate smart agriculture:

i. Farmers training on good agricultural practices: more training and adjusted to the actual – changing - weather. How to handle land, how to improve and guarantee soil quality in close collaboration with SARI.

ii. Farmers need access to real time data and information. They do not have correct and up to date information right now which is a serious missing link in an appropriate agricultural planning. It is also about dissemination and interpretation: how does the information reach them and how is the right interpretation done including correct conclusions for their agriculture? The issue is that MOFA does not have enough resources and that the farmers are not very much willing to pay for these services.

iii. Improved seed and continuous development: adjusted to the actual situation and changing weather. For instance, increased temperatures are a fact, so a heat resistant variety for sorghum is a hugely needed, also in close collaboration with SARI.

iv. Crop insurances: should get attention and be in place.

Irrigation is not common and access to water only via natural sources

Irrigation is not common among the sorghum smallholder farmers so they only have access to rainwater and some to nearby natural water sources like a lake and river. Generally, the farmers adjust their cropping pattern to the season (rainy/dry season) which limits them in their possibilities and makes them also very vulnerable and dependent on external weather circumstances. It also emerged from consultations with commercial farmers, aggregators and plant breeders that dry season sorghum cultivation under irrigation is not very viable financially. This is not only because of the higher cost of production due to the use of irrigation but also high pre-harvest losses as birds prey on the crop, especially when it is the only crop growing in a rather dry environment.

5.2.3 Gender equality

Gender equality is analysed in terms of acknowledgement, acceptance and enhancement of the position of women in the sorghum VC. Is gender equality throughout the VC acknowledged, accepted and enhanced? This is the key guiding question of this section. The theme is divided into five sub-themes: economical activities, access to resources and services, decision making, leadership and strengthening the status of women, and heaviness of work and distribution of work.

Policies are in place but reality is still not very gender friendly and women inclusive

Ghana's gender policy aims to mainstream gender equality concerns in the national development processes by improving the social, legal, civic, economic and socio-cultural conditions of Ghanaians. The necessary legislative frameworks and institutions are in place including a ministry responsible for Gender, Children and Social Protection. However, still women mostly lag behind their male counterparts in terms of productive employment, and have low participation at all levels of (political) decision making. A number of women and girls still suffer from early and forced marriage, sexual exploitation and domestic violence. Significant barriers exist in access to economic resources and participation in public life, which is a manifestation of entrenched socio-cultural constructs and traditional practices. There is under-representation of females in Parliament and across the political and economic landscape (UNDP 2018 and USAID 2019).

The three main constraints for women and gender equality are access to and decisions on credit, workload, and control of assets

The Women's Empowerment in Agriculture Index (WEAI) measures empowerment, agency, and inclusion of women in the agriculture sector in an effort to identify ways to overcome those obstacles and constraints. The WEAI can also be used more generally to assess the state of empowerment and gender parity in agriculture, to identify key areas in which empowerment needs to be strengthened, and to track progress over time. According to the Ghana Country Report 2017 (ActionAid, ActionAid International and ActionAid Ghana), the three main constraints for women are access to and decisions on credit, workload and control of assets. The women in the northern regions report low achievement in access to and decisions on credit, and more than 40% of women have inadequate achievement in workload and purchase, sale, or transfer of assets. This suggests that the key areas to empower women are increasing women's access to credit, improving women's rights to purchase and own assets, and reducing their workload (See Figure 5.5 and Figure 5.6).

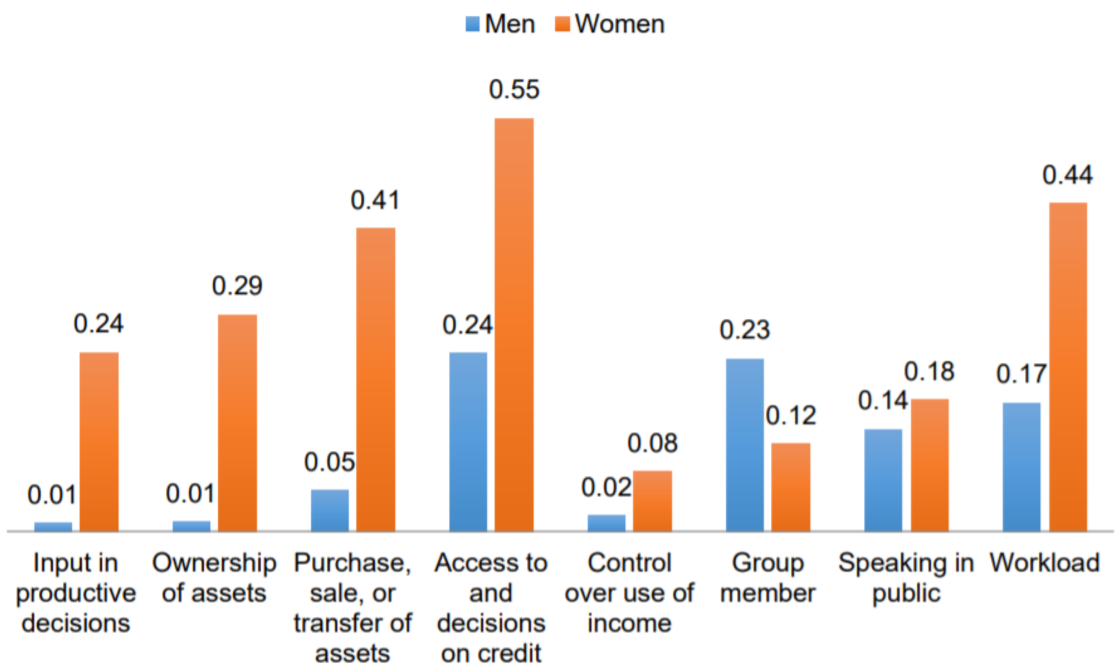

Figure 5-5: Proportion of women and men who have inadequate achievement by indicator 2017
Source: ActionAid (Ghana)

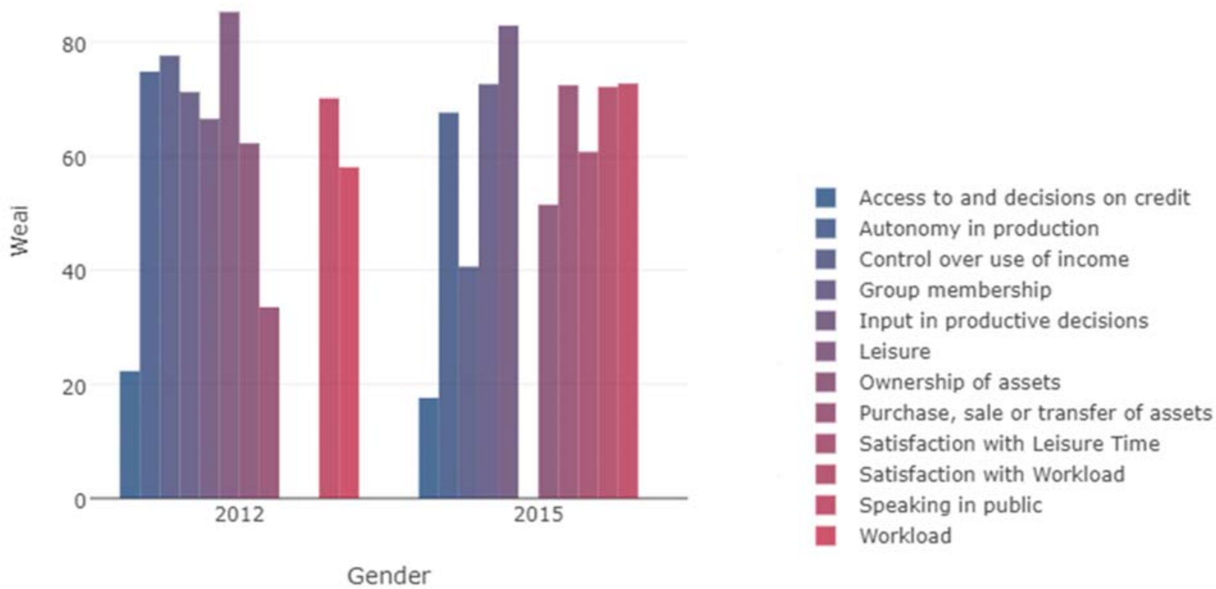

Figure 5-6: The WEAI of 2012 and 2015, Upper West, Upper East and Northern Region of Ghana
Source: USAID

Women participate in economic activities of sorghum value chain

Participation of women in the sorghum VC is quite active. Women are active as producer, worker, trader and pito brewer. The analysis of actors' margins in Chapter 4 demonstrates that all these activities are profitable. In particular, pito brewing is not only profitable but generates incomes which sustain households.

The table below (Table 5.1) shows the number of Farmer Based Organisations (FBOs) in the three production regions and the number of female and male membership. The FBOs are not commodity based so the farmer members produce various crops among which sorghum but the figures show clearly the high membership rates of female compared to male. At the industrial brewery there is female-male policy for staff and women occupy quite important positions in the company.

There are a few risks of female exclusion from certain segments (e.g. formal more advanced brewing, aggregation) which is mainly related to double burden[30] and historical and cultural norms. On the contrary, some VC segments are almost exclusively for women examples including pito brewing, grain retailing in the informal markets (which are dominated by 'the market queens'). Activities such as grain cleaning and sorting are also perceived as women's jobs, not because they are low-paid but due to the perception that women are better at it than men. The involvement of women in the sector was often mentioned as an attractive feature of the sorghum sector. It has given women the opportunity to work in a sector with good general conditions and a relatively higher awareness on the position of women than in other sectors.

Region	Number of FBOs	Active FBO, membership				
		Male	*%*	*Female*	*%*	*Total*
Northern	766	10.646	53.2	9,350	46.8	19,996
Upper East	725	5,121	37.9	8,397	62.1	13,518

[30] *Double' or sometimes even a 'triple burden' refer to women being active as as (salaried) worker, domestic worker and carer for family members*

Upper West	273	1,804	55.3	1,460	44.7	3,264
Total	**1,764 *(37% of total, # 4,743 FBOs nationally)***	**17,571**	**48%**	**19,207**	**52%**	**19,208**

Table 5-1: Number of FBOs and active membership (f/m) per FBO in Northern region, Upper East and Upper West
Source: MOFA (2018).

Women access to resources and services is very low
Access to resources is analysed in terms of assets, credit and services. Women generally have less access to land which in turn limits access to credit. Land rights were historically a privilege for men. Although there are initiatives from women groups, NGOs and the ministry of gender to change this, the general perception is that land rights preferably go to male inheritors, or otherwise the management of it is in hand of the husband. The lack of land rights is a major barrier to obtaining credit and limits women to become member of an association. The limited access to resources is not limited to the sorghum sector but applies to all agricultural sectors in Ghana. For female workers it has less clear consequences.

Decisionmaking power of women active in the sorghum value chain varies per VC stage and activity
Decisionmaking is analysed in terms of autonomy in work and control over income. Women have less decision making power on production decisions. Negotiations and decisions are discussed but at the end, the man decides what will happen in terms of production, harvest and sales. Female have relatively low decision making power in income. Generally speaking, it is the man who decides. Again, this applies to all agricultural sectors in Ghana and is not a specific feature of the sorghum VC.

However, female workers (e.g. input-dealers, post-harvest workers, pito brewers, market queens) seem quite autonomous in the organisation of their work, there is a strong task division among male/females and the tasks of a women: she decides quite autonomously on her own activities and the expenditure of her income.

Leadership and empowerment of women active in sorghum is quite low
The field visits and FGDs showed that group membership is equally important for both men and women with the Village Savings and Loans Associations being most popular amongst women. Many women 'inherit' their membership of on the passing of their husbands, and a great deal of work has been done by NGOs and development programmes in Northern region, Upper East and Upper West to promote women's involvement in groups. Both men and women express that women can be appointed to leadership positions and we met several strong female leaders. However, women also expressed that the majority does not envision a leadership position as it comes with more tasks and obligations. They simply do not have time left considering all their tasks (see the following paragraph on Hardship of labour and task division).

Hardship of labour and task division: unequal reality
Hardship and division of labour analysed in terms of workload and strenuous work. The majority of tasks at household level and workloads of the household burden the woman: domestic work, child care, gathering market information, selling of own produce at spot market, active in production of crops, harvest and have often job(s) for additional income. That means that overall workload for women and female workers is higher because of domestic work. Women in general have responsibilities not only at work, but also when their day ends. This is true for women in general, and even more so for female wageworkers who are single mothers. Female producers and workers seem to be protected from the strenuous work in the field. At production stage for example, pesticides are hardly applied in sorghum and when needed, men take care of application. It is not yet clear whether women are protected from strenuous work at the breweries. The exposure of women to harsh, risky conditions in brewing pito as well as in carrying heavy jerrycans (of water) and pots was mentioned in discussions in Section 5.2.1.

5.2.4 Food and nutrition security

Food and nutrition security is analysed in terms of availability, accessibility, utilisation and nutritional adequacy and stability. Are food and nutrition conditions acceptable and secure? This is the key guiding question of this section. The theme is divided into four sub-themes as defined by availability of food, accessibility to food, appropriate use of food, stability in time of availability, access and use of food.

Availability of food is in general not a big challenge in Ghana and according to the sorghum VC actors

Availability of food is analysed in terms of local production and local food. Availability of food is the first component of food and nutrition security. Availability refers to "the provision, supply or stock of food, i.e. it relates to the "supply", food production, production infrastructure, inputs and food production chains, and national and international net trade"

The Global Food Security Index (GFSI 2018) ranks Ghana as 73th out of 113 countries worldwide (1=best). Ghana ranks relatively high compared to neighbouring countries, i.e., Benin ranks 90, Togo 93, Nigeria 96 and Burkina Faso 97. But Ghana performs worse in terms of food consumption as a share of household expenditure, food loss and diet diversification. The survey respondents indicated how much of their income is spent on food for the household (Table 5.2). 25% allocates 25% of the income to food, this is 50% for 30% of respondents and 31% spends 75% or more of their income on food. As a reference, data on food budget shares of Nigerian show that the average Nigerian consumer spends 73% of his/her income on food products (IMAP, 2010).

Table 5-2: Food expenditures in households (September 2019)

Food expenditures (share of income in %)	Number of respondents sorghum survey (in %)
25%	25%
50%	30%
75% or more	31%
I have no idea	2%
no data	12%

Source: Sorghum VC survey, September 2019

High regional differences: northern Ghana very poor and higher FNS insecurity

Ghana is also marked with wide disparities across the country, northern Ghana generally scores much lower than southern parts and is marked by higher poverty levels (see also section 6) and food and nutrition insecurity Agricultural growth is the major driver of poverty reduction in the regions of sorghum production, i.e. Northern, Upper West, Upper East, North East and Savannah Regions which are characterized by high poverty and malnutrition. Despite various interventions and improvements (poverty fell by nearly 12% and the prevalence of child stunting dropped by 18%), still, 29.9% children are stunted (Ghana population-based survey (PBS) 2015). Additionally, wasting is a serious public health concern: 50% of the districts where PBS had sufficient sample size, the prevalence of wasting was above the emergency threshold level.

Poverty alleviation strategies and food and nutrition security (FNS) in Northern Ghana is high on the agenda

Not only by a significant number of non-governmental organisations active in northern Ghana (often called the donor darling of Africa) but also by the government of Ghana (GoG). In 2018 the new Ghana's Global Food Security Strategy (GFSS) Country Plan 2018-2022 was launched and presents a five-year integrated whole-of-government strategy as required by the Global Food Security Act of 2016. This Country Plan reflects an evidence-based, integrated, interagency approach for Ghana to achieve the GFSS goal of reducing poverty, hunger, and malnutrition through the three objectives of agriculture-led growth, resilience, and nutrition while positioning the country to become self-reliant.

Sorghum VC actors experience periodic food security challenges

According to the stakeholders interviewed during the mission, local food production and supply is not one of the main challenges, but they face food and nutrition challenges in the months June, July and August. Food stored for household consumption is exhausted or is sold for some additional cash to purchase agricultural inputs or pay for services to prepare the land for the new planting season. Many of the staple foods are produced in the region or nearby, including maize, rice, millet and cowpeas, soybeans and groundnut. Maize and rice are perceived as the two main food crops and sorghum (especially the white variety) as a cash crop since the breweries provide a guaranteed market. The traditional (red sorghum variety) is consumed at household level and is preferred for brewing pito. Sorghum nutritional values are very high (see section below).

Accessibility of food is challenged
Accessibility of food is analysed in terms of income allocation to food and consumer prices. Accessibility of food is the second component of food and nutrition security. It relates to "the way that people obtain food, both physically and economically, be it trade, self-production, access to markets, income increase due to programs and other social protection instruments and direct food aid". For this study, guiding questions for this section were: i) do people have more income to allocate to food? and ii) are (relative) consumers food prices decreasing?

The majority of the interviewed stakeholders indicated to have problems temporary in accessibility of food. The interviewees, survey respondents and the farmers participating in the FGDs have food shortages in the months June, July and August (see also Food Availability section above). At that time the outputs of previous season used for domestic consumption is almost exhausted, farmers have to spend their income on farm inputs and land preparation and they sometimes have to sell food to be able to purchase their farm inputs. The sorghum smallholders produce maize (supported by the government and other interventions) for domestic consumption. Also rice, millet and cassava are produced for household consumption and to a limited extent sorghum. Planting and harvest of the cereals (sorghum, rice and maize) usually occur within the same period.

There is sometimes a shortage of food leading to smaller portions and rice is sometimes too expensive to buy (in the off season). Another issue is low accessibility of other food items to complement the meal like vegetables, fruit, meat and fish which are rarely available in the northern regions of Ghana. The survey respondents indicating to consume vegetables (e.g. tomato) on a daily basis is quite high though, 79%. Regular chicken and meat consumption is low: 6% reports daily consumption and 20% has access to meat and or chicken on monthly basis.

It is not yet known (or visible) whether sorghum as a cash crop with a guaranteed market leads to an increase in household income leading in turn to an increase in income allocation to food. Often higher income at smallholder household level does not lead to an increase in food consumption expenditures. Food expenditures are quite high as 30% of the survey respondents indicate to spend half of their income on food and 31% spends at least 75% of their income on food.

Utilisation and nutrition: maize, rice, millet and soybean are the food crops in Ghana
Utilisation and nutritional adequacy is analysed in terms of income allocation to food and consumer prices. Utilisation and nutritional adequacy of food is the third component of food and nutrition security. It relates to "the influence of food quality on the nutritional status of individuals and their health. This includes hygiene; sanitation; quality and food safety; nutritional information, and the way the body uses the nutrients (FNS)". Guiding questions for this section were: i) is the nutritional quality of available food improving?, ii) are nutritional practices being improved? And iii) is dietary diversity increased?

In Ghana, maize is the most important staple crop for food security, accounting for more than 50% of total cereal production in the country. Maize is followed by rice, millet and soybean. Maize is prevalent in the Northern Regions and is planted mostly by smallholders. Maize cultivation is supported by governmental interventions (e.g. subsidized fertilizer and availability of improved varieties). A typical Ghanaian diet in the northern regions is high in calories, but not in terms of nutritional value. The Ghanaian diet largely relies on starchy roots (cassava, yams), fruit (plantain) and cereals (maize, rice) (FAO 2018). Starchy roots and cereals still supply almost three quarters of the dietary energy and diversity of the diet remains low. The dietary supply meets population energy requirements, but the share of protein and of lipids in the dietary energy supply is lower than recommendations. Rapid urbanization has modified food consumption patterns in urban areas, with an increasing demand for imported food, especially wheat and rice. Over the last decade, prevalence of undernourishment has decreased considerably. However, food insecurity persists, mainly due to unstable production, insufficient purchasing power and problems of physical access due to a lack of road infrastructure in the northern part of the country. There is a limited availability from the south but transportation and handling of vegetables and fruits from the south lead to high prices and as such it unaffordable for the majority of people in the north.

Malnutrition is decreasing but poor nutrition levels in Northern Ghana
According to UNICEF, 2013 in Ghana showed levels of malnutrition dropping, 23% of children are still stunted and 57% are anaemic. The Ghana Living Standards Survey GLSS 2014 showed that nutrition is particularly poor in Northern Ghana, where almost two in every five children are stunted and more than 80% of children suffer from anaemia. Although stunting is still high, there has been a substantial decline in the prevalence of the past decades.

Figure 5-7 (from GSS 2014) shows that the proportion of stunted children in the country declined from 31% in 1998 to 19% in 2014. According to 2015 PBS data, stunting exceeds 40% in four of the Region's 25 districts. High prevalence of stunting in the north is strongly correlated with poverty and inappropriate nutrition practices (e.g. diets highly reliant on starch and low consumption of proteins and green leafy vegetables and fruits). Micronutrient deficiencies—hidden hunger—persist. Anaemia is a severe public health problem in Ghana, especially among children and women of reproductive age, and rates are particularly high in northern Ghana. Nationally, 66% of children suffer from anaemia; though rates in the Northern Region reach 82%. Anaemia is a serious concern for children given it can impair cognitive development, stunt growth, and increase morbidity from infectious disease (Unicef 2013, GLSS 2014).

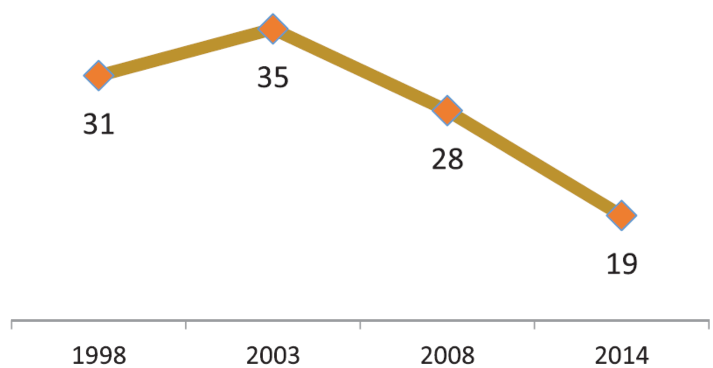

Figure 5-7: Prevalence of stunting in children < 5 years (in %) in Ghana Demographic and Health survey (GSS 2014)

Sorghum: very nutritious crop
From a nutritional composition standpoint, sorghum is comparable to wheat (without containing gluten) in that it is high-complex carbohydrate, high-protein grain. Sorghum is a great source of riboflavin, Vitamin B6, thiamin and minerals such as iron, potassium, manganese and magnesium. A report by Kulamarva et al (2009) shows that 192 gm of sorghum grain is loaded with 632 Kcal which offers a calorie rich diet with other minerals and vitamins. It possesses huge amount of carbohydrates, with 40.78% protein, 18.97% fat, 2.50% calcium and iron, vitamin B1, and nicotinic acid in small amounts. It is also believed that sorghum prevents cancer, can be used to control diabetes, prevents anaemia and increases the level of energy (Kulamarva et al ibid).

Pito beverages can contribute to a healthy diet but consumers should mind the brewing
Although we were quite sceptic towards a stimulation of increased beer consumption, the mission and desk study showed that pito is quite healthy, both the unfermented as well as the fermented (alcoholic) drink. The local traditionally brewed alcoholic beverage is called pito and is golden yellow to dark brown in colour. It is preferable made of the red traditional sorghum variety. It has a taste varying from slightly sweet to very sour and contains sugars, lactic acid, amino acids, 2-3% alcohol, proteins and vitamins (Ekundayo 1969). Studies by Kolawole et al. 2007, looking at the nutritional composition and microbial analysis of pito found out that they contained mineral elements such as calcium, magnesium and iron. The study of Duodu et al 2012, showed the mineral profile of pito samples indicating the presence of both essential and toxic metals. With the exception of Mn, all the essential minerals measured were below the recommended maximum limits. Hence pito is a good source of K, Na, Fe, Cu and Zn. The detected concentrations of Ni, Pb and Cd in the pito samples were above the respective maximum World Health Organisation (WHO) guideline in water. This can be attributed to poor handling during preparation or the utensils used for the production and not from the raw materials (grains) used. Therefore, pito is susceptible to metal contamination due to poor handling and primitive equipment used in the production. To conclude, pito and sorghum beverages are contribution to a healthy diet but consumers should be apprehensive of the environment where the pito is prepared.

Sorghum beverage for children: a missed opportunity
A missed opportunity is the taboo on the unfermented pito and the negative perception among Christians and Muslims. It is very healthy and nutritious for children but the line between fermented and unfermented liquid is vague, as such it is deemed as risky for children to drink as the fermentation process might have started and some

sources indicated that some children do actually drink the leftovers of the liquid when fermentation has started. In other words, they do drink the pito, the alcoholic version.

Figure 5-8: Photo of pito consumption shed close to brewery (brewer being interviewed) in Upper West, Ghana
Source: Team (May 2019)

Stability

Stability is analysed in terms of potential food shortages and extreme price variations. Stability is the final component of food and nutrition security. This dimension is related to the resource and resilience indicator of the GFSI index which clarifies countries risks and adaptation measures. This dimension relates to "the capacity to react to unforeseen economic, political and social crisis and natural disasters that may change the conditions of the other dimensions creating risk and vulnerability". Guiding questions for this section were: i) is risk of periodic food shortages for household reduced? and ii) is excessive food price variation reduced?

Cost of food in Ghana increased 7.30 percent in April 2019 over the same month in the previous year.

Food Inflation in Ghana averaged 7.58 percent from 2013 until 2019, reaching an all-time high of 9.70 percent in December of 2016 and a record low of 5 percent in July of 2014 (Trading Economics 2019). According to the WorldBank (2017), household final consumption expenditure in Ghana was 11.3% of total household income. At this stage we are not aware of serious food price fluctuations as reliable data is quite outdated. There is a study of 2011 analysing data over the period 1970 to 2006 and the data used were monthly wholesale prices for maize, millet, and rice obtained from MoFA. The results reveal that foodstuff prices exhibited high volatility with continual increasing prices over the study period. The results revealed that maize, millet and rice prices increased by 23%, 11% and 10% respectively. The authors recommend the provision of adequate storage facilities, and farmers' market centres in the districts to stabilize food prices. The increases in food prices have implications for food and nutrition situation of the poor in Ghana (Kuwornu and Mensah-Bonsu 2011). Another study of 2013 (Osei-Asare and Eghan) reveals that cereals and bread; fish; vegetables; and roots and tubers will continue to constitute important share of Ghanaian food expenditure as they collectively constitute 67% of future food expenditure. Food price inflation between 2005 and 2011 has eroded real household food purchasing power by 47.18%.

5.2.5 Social capital

Do formal and informal farmer organisations/cooperatives participate in the value chain? How inclusive is group/cooperative membership? Do groups have representative and accountable leadership? And are farmer groups, cooperatives and associations able to negotiate input or output markets? Is social capital enhanced and equitably distributed throughout the VC? These are the key guiding questions of this section. The theme is divided into three sub-themes: performance of producer organizations, access to information and trust between agents of the chain, and social commitment of the populations.

Farmers are organised but not specifically in sorghum; most common organisation form is the FBO
The Farmer Based Organisations (FBOs) are not commodity based. Farmers are often clustered according to area and not based on a specific crop so there are no particular sorghum farmer groups or cooperatives. The majority of farmers in the three regions produce various crops due to the dry and rainy season. As indicated before, the main crops are maize, rice, soya, sorghum, millet, cowpea and groundnut and FBO-members cultivate all. Approximately 79% of the FBOs are registered (IFPRI 2001) and they can request membership of the Department of Cooperative, the District Assembly, MoFA, Registrar Generals Department, and the Farmer Union.

Weak producer organisations
In the past two decades, Ghana has witnessed many governmental and nongovernmental projects (see Salifu et al. 2010) seeking to promote FBO development. In particular, between 2000 and 2007, the World Bank alone invested more than US$9 million for the development of FBOs as part of AgSSIP (AgSSIP 2007). In 2007, the Millennium Challenge Corporation (MCC) also approved a five-year US$547 million anti-poverty compact with the Government of Ghana and a significant proportion of this amount has been used in the development FBOs. Salifu et al (2010) estimated the number of FBOs in Ghana to be around 10,000 although MoFA figures estimate approx. 4,700 FBOs (see table in Figure 5.9 below). According to MoFA FBOs provide opportunities for farmers to benefit from economies of scale, better bargaining power and a stronger voice in policy development. Well- organized FBOs promote farming as a business, with linkages along the product value chain. Therefore, MoFA identified the FBOs to achieve the goal of a modernized agricultural sector contributing to food security, employment and poverty reduction (MoFA 2018). See below a summary of the number of FBOs per region and active membership (source MoFA 2017-2018). Out of the previous ten administrative regions, the regions of sorghum production, Northern (#766), Upper West (#725) and Upper East (#273) represent 37% of the total number of FBOs (#4,743). Only Volta region has more registered FBOs.

Region	Active FBOs					
	Number of FBOs	Membership				
		Male	%	Female	%	Total
Greater Accra	137	5,966	69.9	2,573	30.1	8,539
Eastern	496	6,597	72.7	2,475	27.3	9,072
Central	264	5,280	66.7	2,640	33.3	7,920
Volta	822	2,310	45.3	2,787	54.7	5,097
Western	141	2,453	60.0	1,635	40.0	4,088
Ashanti	534	9,113	56.9	6,911	43.1	16,024
Brong Ahafo	585	7,327	68.3	3,394	31.7	10,721
Northern	766	10,646	53.2	9,350	46.8	19,996
Upper East	725	5,121	37.9	8,397	62.1	13,518
Upper West	273	1,804	55.3	1,460	44.7	3,264
Total	**4,743**	**56,617**	**57.6**	**41,622**	**42.4**	**98,239**

Figure 5-9: Regional summary of farmer based organisations (FBOs) in Ghana
Source: MOFA (2018)

Increasing rural collective action to achieve agri-business development objectives
Many note that the rapid rise of FBOs is partly due to NGOs, government agencies, and private investors who increasingly see rural collective action as one important means to achieve agri-business development objectives. Although there has always been some form of collective action among neighbouring farmers (usually relatives and

friends providing each other with reciprocal labour support on their fields, especially weeding), the performance of the more formal FBOs is generally low (Salifu and Funk 2012) and there is high dependence on external support. One of the assumed reasons is that the FBOs are organised by outsiders and not by the farmers themselves. So motivation to organise is mainly an extrinsic one to provide for vehicles to receive an array of collective services (e.g. extension services, knowledge transfer, inputs or aggregation services and payment (via nucleus farmers). At this stage, it seems there is rarely an intrinsic motivation for farmers to be organised, to perform collectively and professionalize into formal cooperatives. Farmers hugely depend on external support and their nucleus farmer. Although there have been cases of mistrust, of late or no payment from the nucleus farmer to the farmers, the farmers have no power or possibility to turn against him as he is often a respected elder from the community.

Information is scarce and confidence levels between sorghum VC-actors is low

Information, price information, knowledge and quality advisory services are hardly available or accessible to smallholders. If they have information it is not sure whether the information is accurate and reliable. They often rely on the nucleus farmer who is in charge of (price) negotiations with the input-suppliers and the aggregators.

Based on the interviews, the FGD and the perception of the stakeholders met trust levels are not very high between VC actors. Contracts are in place between farmers and their nucleus farmer and between the nucleus farmer and the aggregator. However, it seems contractual arrangements are no guarantee of compliance and enforcement and penalties hardly occur. The system is a trust-based system but trust is generally low between and among the sorghum value chain actors. One of the reason is the lack of transparency, of monitoring and control and traceability. The lack of internet/network, remote and inaccessible rural areas, cash transactions are all factors contributing to a challenged trust and confidence. It makes is very easy to cheat, to free-ride and to blame others or the system and there are no protection, regulation or monitoring systems in place. A contract has to be in place but even written and signed agreements are not complied to. We have also anecdotal stories of VC actors paying only after having received the order (e.g. malted grains) and having checked the quality. During the two missions we have observed several issues on payments, payment delays and distrust. Low trust levels are not only related to delayed payments. Also the lack of information, or incorrect information hampers trust and effective relationships between the VC actors. One striking example is that the sorghum farmers are not directly contracted to the industrial brewery and therefore there is no direct negotiation on supplies and prices between them. Hence, the trickling down of price information to farmers is sometimes slow and inefficient. This contributes to lack of transparency and trust, especially at the level of farmers.

Monopoly and power imbalances in sorghum chain hampering efficiency and growth

There is no or rare direct communication between value chain actors upwards or downwards in the chain. The lack of a sector platform where representative of each stage and activity meet and interact hampers a trustworthy and open relationship. There is also the risk of one bigger actor, the market, governing the chain with a 'rule and divide' policy. The industrial brewery tends to have unique and confidential agreements with the participating commercial farmers and the aggregators, each of them being perceived as receiving 'special treatment' and therefore being reluctant to join forces, especially in negotiating contracts.

Social involvement guided and controlled by the traditional chief governance system

The guiding questions on social involvement are: Do communities participate in decision that impact their livelihoods?; Are there actions to ensure respect of traditional knowledge and resources?; Is there participation in voluntary communal activities for benefit of the community?

Communities participate in decisions that impact their livelihoods via community representatives

The village or community chief sometimes accompanied by influential family heads. The traditional chief system is very important and influential. At household and farm level, people can decide how they want to live, what they want to cultivate. At village and community level, the chiefs have to be involved in all decisions impacting livelihoods and have the final say. There are actions and systems in place to respect traditional knowledge and resources. The main system is the traditional chief system as described earlier. There is a tradition of oral knowledge transfer which is highly esteemed. The pito brewing process is a traditional activity transferred from mother to daughter. The pito drinking is also a very important and respected social activity where information is shared, stories are told. It is a daily activity for the neighbours and people in the near environment whereby they not only enjoy their drink but also enjoy company, exchange news and information and have lively discussions.

There are plenty of civil society organisations in the northern regions of Ghana.

All kinds of programs, themes and approaches have the aim to stimulate community development. A common approach is to work via and with community based organisations which are often voluntary structures. Also the government uses these kinds of informal and voluntary community structures to improve the community with the Community-based Health Planning and Services (CHPS) Initiative. The CHPS initiative has employed strategies to guide national health reforms that mobilize volunteerism, resources and cultural institutions for supporting community-based primary health care

5.2.6 Living conditions

Living conditions, the 6th sub-domain, are analysed in terms of access to health services, housing, education and training. The guiding questions per subdomain are:

- Health services: Do households have access to health facilities?; Do households have access to health services?; Are health services affordable for households?
- Housing: Do households have access to good quality accommodations?; Do households have access to good quality water and sanitation facilities?
- Education: Is primary education accessible to households; Are secondary and/or vocational education accessible to households?; Existence and quality of in-service vocational training provided by the investors in the value chain?

Livelihoods in general: progress on Human development Index but huge regional disparities

Despite its global standing as a stable, richly-resourced, lower-middle income, democratic country, Ghana faces enormous development challenges. Ghana was ranked 140 out of 189 countries on the 2018 Human Development Index (HDI). Between 1990 and 2018, Ghana's HDI value increased from 0.455 to 0.592, an increase of 30.1 percent. Despite this progress, there are wide disparities across the country. The Northern Region stands out as the one having made the least progress in poverty reduction and now makes up the largest number of poor people of any of Ghana's sixteen regions. Poverty is not only more pervasive in the north, but the depth of poverty is greatest in the Northern Regions. This gap between the north and the rest of Ghana is, in large part, due to its geography and agro-ecological differences. The south has two rainy seasons, while the north has only one and is heavily dependent on subsistence agriculture. In common with neighbouring Sahelian countries, the north is experiencing increasingly erratic rainfall. Furthermore, farming communities in the north traditionally have had few alternative livelihood opportunities (GFSS 2018).

Poorest populations in Northern Ghana.

With an expanding underemployed youth population, poor nutritional outcomes, and a growing north-south divide where close to 60% of the poorest populations reside in the Northern regions. There are huge differences between the northern and southern Ghana. Poverty and nutrition statistics are poorest in the Northern Ghana (i.e. the production areas of sorghum) (GFSS 2018) and Figure 5.10 below.

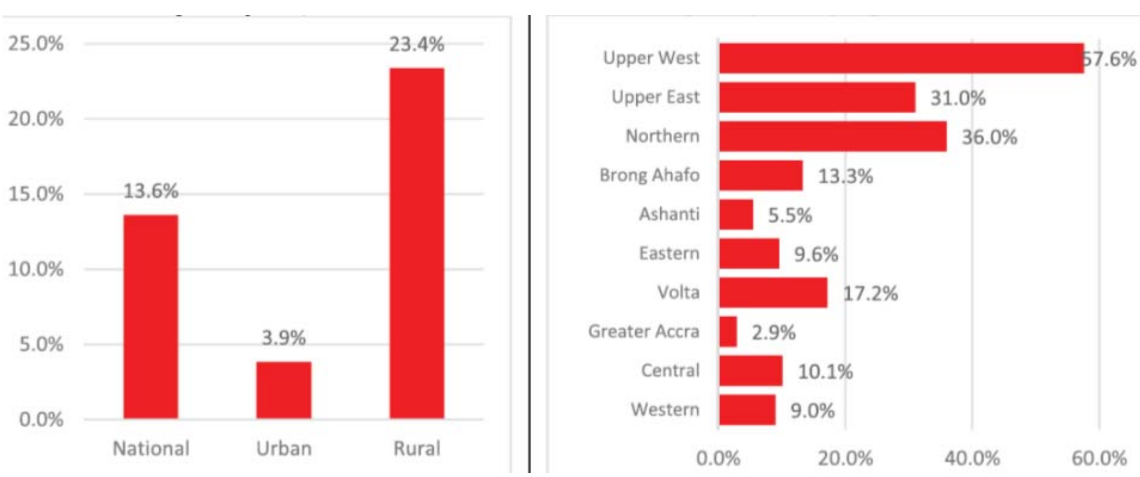

Figure 5-10: Proportion of population living below the international poverty line, 2013 and by region

Source: Ghana Living standard Survey Round 6, Ghana Statistical Service (2014)

The Indicator in this figure provides the proportion of the total population and the proportion of the employed population living in households with per capita consumption or income that is below the international poverty line of US $1.90 a day.

Low access to health services, drinking water and sanitation facilities

In addition, low access to health services, poor water, sanitation, and hygiene (WASH) practices contribute to undernutrition and challenged population health. Households in northern Ghana have particular challenges. There are few toilet facilities at the household level, and open defecation rates range between 71% and 89% in the northern regions where sorghum production takes place. Water sources are often far from home and are typically a river or stream. Over 90% of households do not treat their water prior to drinking and eight out of ten Ghanaian households do not have hand washing facilities due to cost (UNICEF 2018). The national numbers of the Ghana living Standard Survey 2016 (GLSS 7) are quite positive on increased access to flush or KVIP toilets. However, the large regional disparity still remains with the rural areas lagging far behind. In 2016/17, only 13% of households had access to flush or KVIP toilets in the Upper East Region, while about 86% of households had access to flush or KVIP toilets in the Greater Accra Region.

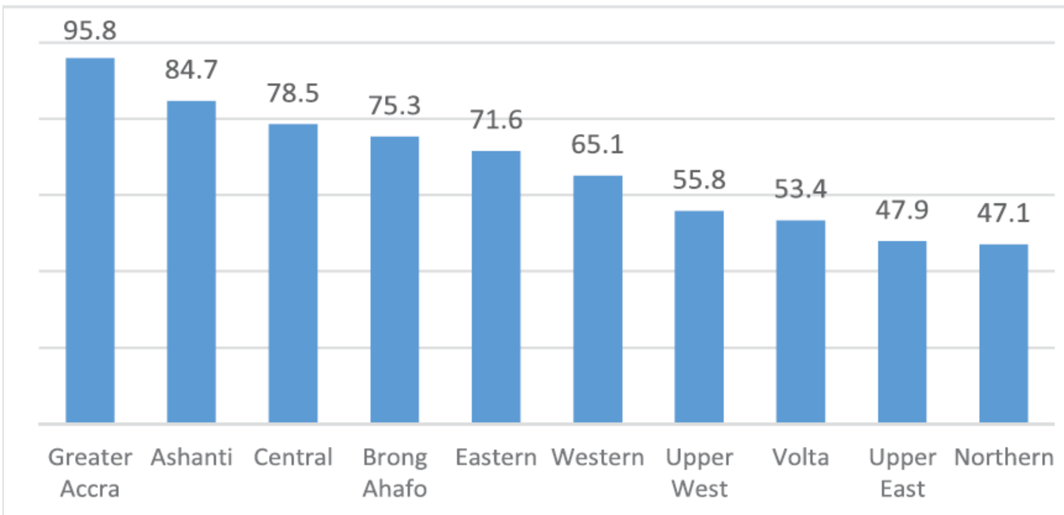

Figure 5-11: Basic and safely managed drinking water coverage by region (2015) in Ghana
Source: WHO/UNICEF (2017)

Figure 5.11 above shows figures on basic and safely managed drinking water coverage by region (WHO/UNICEF 2017). Greater Accra Region has the highest coverage for basic and safely managed drinking water, followed by Ashanti Region. The region with the least coverage is the Northern Region, followed in ascending order by the Upper East and Volta Regions.

Community-based Health Planning and Services (CHPS) has been promoted as a strategy to support community-based primary health care

Ghana has made major strides in improving access to health care in the past decade. The number of doctors and nurses per population has increased (Ministry of Health Ghana 2013). There has been an increase in coverage by health facilities and Community-based Health Planning and Services (CHPS) that has been promoted as a strategy to support community-based primary health care (Health Sector Medium term Development Plan 2014–2017). In 2003, the National Health Insurance Scheme (NHIS) was created to provide (financial) access to quality basic health care for residents in Ghana, adopting free maternal care in 2008 and free mental health care services in 2012. Despite these efforts, Ghana did not reach the Millennium Development Goals (MDGs) 4 and 5. With respect to access to non-communicable diseases and mental health services, the achievements made are modest, with lack of adequate information on the size of the burden of non-communicable disease (ibid).

Inequity in accessing health care services has been highlighted as one of the problems that needs to be addressed to improve health outcomes in Ghana (World Bank 2012).

The distribution of human resources and health facilities varies among and within regions (Human Resources for Health 2010). Urban populations and richer households are more likely to have a valid NHIS card than rural and poorer households (National Health Insurance Authority 2012, Ghana Statistical Service 2011). Pregnant women from poorer rural households deliver less often in a health facility than those from richer households. Under five, mortality is higher among the poorest than among the richest (ibid). The financial difficulties the country is experiencing since 2012 are risking the NHIS achievements, bringing illegal payments for all users including children and pregnant women.

Sorghum VC actor less positive on access to health facilities

Officials and formal figures are quite positive about access to health care facilities with the CHPS with primary focus on communities in deprived sub-districts and bringing health services close to the communities. The data collected in the sorghum study give a different picture of the success of the CHPS. In reality the medical health care post is often closed; has no experienced staff around; and in 90% of the cases there is a lack of basic medication (e.g. anti-malaria medication). There is no transportation or ambulance to treat emergencies and if cash is available the patient needs to arrange transport with a tricycle to reach an hospital or medical health care facility in town. According to the survey data 80% has access to toilet facilities and 92% to safe drinking water. Access to health facilities is also high (99%) but affordability of health care services is lower (83%). These figures are aggregated results of all the respondents surveyed in the course of this study (94 respondents in total), from smallholder producers to aggregators, traders and pito brewers.

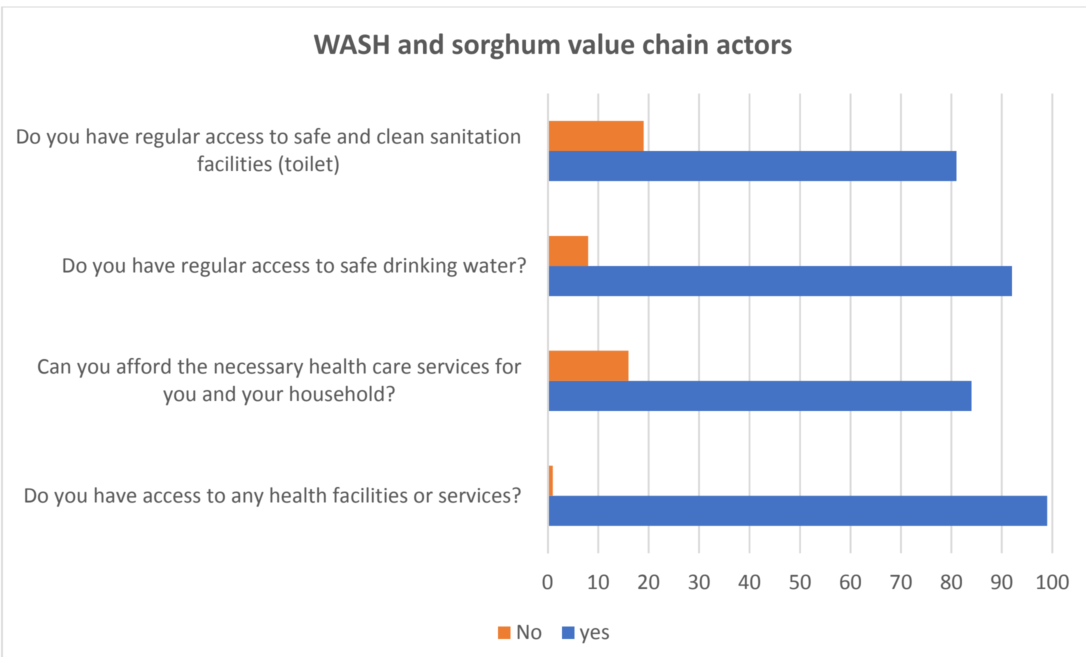

Figure 5-12: WASH and sorghum VC actors

Source: Sorghum value chain survey (October 2019)

Housing quality improved but majority of houses is still traditional in the rural areas

The majority of houses in the rural areas of the three regions under study are the traditional huts of clay. These houses are constructed with locally available materials - mud, thatch, grass – hence have a lesser durability compared to modern houses. The structure, look and materials used in traditional housing are largely dependent on the weather conditions in the location, available materials and ethnic groups. Most of the rooms have poor or no ventilation and the walls are cracked, allowing dangerous insects to creep in during rainy nights. Women cook under the sun. Most of these houses lack basic amenities like toilets or bath houses. Sometimes there is no electricity and water and women have to walk long distances to get water. Bathrooms are usually wooden structures erected outside the house (to the armpit or shoulder level) and a piece of cloth used as screens during bathing.

Shift from traditional to more modern constructed houses.

There are no official figures on traditional and modern houses in the rural areas but the team has the impression that the number of modern houses increased significantly in the recent 5 to 10 years. The stakeholders interviewed and the MOFA confirmed this perception. At the FGD with the famers they acknowledged development in their community and a shift from traditional to more modern constructed houses. Some attributed their improved houses to the income from the sales of the white variety of sorghum. It also appeared during the FGD and surveys (reported below in Table 5.3) that even though there are improvements, the majority of houses is still very traditional: 66% of respondents have houses with grass and iron sheets as roofing and 48% still with mud brick walls.

Table 5-3: Housing in sorghum-growing communities in Northern and Upper West Regions in Ghana

Own house	
yes	43%
no	50%
no data	7%
Roofing house	
Grass and iron sheets	66%
no data	34%
Walls house	
Mud bricks	48%
Cement blocks	18%
no data	35%

Source: Sorghum VC Survey (October, 2019)

Large regional variation in access to electricity

In all the regions in Ghana, access to electricity significantly increased in the last 12 years (GLSS 7). Between 2005/06 and 2016/17, the percentage point increase in access to electricity was most remarkable in the Upper West Region with 48%, followed by the Volta Region (44%) and the Central Region (42%). However, the regional variation in access to electricity is still large, with less than half the households of Upper East having access to electricity, while 94% of households in Greater Accra have access to electricity in 2016/17 (GLSS 7). The research team is convinced that access to electricity in the rural areas is far less as all the participants of the FGD and interviews had no access to electricity. Only the fortunate living near the main road had access to electricity.

Education & Training: primary and secondary education in theory accessible, progression rates low

Primary and secondary education is generally well accessible and used, but Technical and Vocational Education and Training (TVET) is still a challenge. But also progression from primary to secondary is very low: for every 100 children who enter primary, only 38 leave secondary. Ghana has devoted substantial resources to the education sector in recent years and has exceeded associated international benchmarks when including internally generated funds. The vast majority of funding to the education sector comes from the government budget, with government contributing 87% in 2012 and 78% in 2015.

But although indicators of access at the basic education level have improved considerably, there are still large inequities by income, region, location (rural–urban), and gender (Education Strategic Plan 2018–2030, Ministry of Education 2018). The majority of the growth in the number of schools from 2010/11 to 2016/17 has come from the private sector, which operates about a third of the total basic schools in the country. While over 20% of basic school pupils are enrolled in private schools, they are also unevenly distributed across the country, accounting for over 60% of enrolment in Kindergarten (KG) in the Greater Accra region and less than 10% in the Upper West Region. The incidence of poverty is highest in the northwest of Ghana and lowest in the southeast; these trends are strongly correlated with the regional distribution of the proportion of the population living in urban areas and the proportion of educationally deprived districts (ibid).

According to the Ministry of Education, over 450,000 children are out-of-school; they come mostly from the poorest households and within the northern regions where sorghum production takes place. There is a number of factors that may be contributing to the number of out-of-school children in these regions:

- the shortage of classrooms;
- the shortage of (qualified) teachers (large regional disparities in pupil-teacher ratios and weak correlation between the number of students and teachers within a district);
- absenteeism of teachers;
- parent(s) cannot afford own contribution (fee, uniform and materials).

Of those who complete nine years of basic education, only 54% of males and 43% of females acquire literacy skills that are likely to persist through adulthood. There is hence a strong need for adult literacy programmes, even for those who have attended formal schooling. Again, these percentages are lower in the northern regions and as a result general literacy levels in the northern regions are quite low.

TVET face a number of challenges. First of all, there is a mismatch between the skills supplied in TVET institutions and demand for skills in the labour market, and there is also low industry investment and involvement in this sub-sector. Second: capacity, only 52% of technical and vocational institute teaching staff possess technical qualifications, while staffing norms and standards vary substantially throughout the country. Learning outcomes in this sub-sector are also poor, especially for students at the Technician level, with only 30% of students on average passing the Technician I examinations.

All stakeholders interviewed indicated that primary and secondary education is free of charge but the fee, uniform and materials have to be paid for by the parents. This contribution is sometimes the barrier for parents to send their children to school. Especially when financial returns of the harvest were disappointing or when payment of produce is delayed. The information from the FGD showed that even primary education is not available/accessible in a number of cases: yes, a primary school was available but at 2 hour walking distance (one way) or impossible to reach in the rainy season (impossible to cross the river). Of the farmers who participated in the survey, 95% of their children of school going age are actually in school.

5.3 Social profile summary

Table 5.4 below summarizes the main challenges per actor gathered via surveys, FGD and interviews. It clearly shows some common denominators, challenges which occur at various stages of the VC. One challenge which farmers frequently cited is late payment for grains supplied. Other challenges at production stage include attack by birds and limited access to agro-inputs. Another common challenge is lack of proper storage and appropriate transportation. In addition to the outcomes of the social analysis alongside the six research domains, it is important to take into account the challenges experienced and listed by all the actors if the sorghum VC is to be strengthened.

Actor	Main challenge 1	Main challenge 2	Main challenge 3	Main challenge 4
Aggregator	Lack of proper storage	Delays in payment as it occurs only when stocks are taken into the warehouse of the brewery.	Lack good transportation	
Agric extension staff	Lack of inputs for SHF			
Commercial farmers	Lack of labour	Birds attack		
Lead farmer	Inadequate availability of and access to inputs and tractor services	Late payment by aggregators	Birds attack	Lack of equipment (treshing)
Smallholder farmer	Inadequate availability of and access to inputs and tractor services	late payment by aggregators	Birds attack	Lack of equipment (treshing)
Pito brewer	Low patronage	Lack of (financial) support or access to credit	Poor packaging of pito	high sorghum price in off season
Wholesaler	Inadequate storage Facilities	Price fluctuations	Poor transportation	
Trader	Low patronage	Seasonality in supply		

Table 5-4: Main challenges listed by actors in the sorghum value chain in Ghana (2019)
Source: Interviews, surveys, FGDs during study in 2019

Figure 5.13 below gives a visual representation of the social analysis with a spiderweb covering the aggregated scores of the six research domains. Table 5.5 below gives a summary of the main issues per area studied. The spiderweb shows that dimension 1, Working Conditions, scores relatively high (mainly influenced by good working conditions at the industrial brewery). Working conditions is followed by Food and Nutrition Security and Living Conditions. Land and Water rights has the lowest score, followed by Gender Equality and Social Capital. The figure and table clearly show that there is room for improvement in the sorghum sector and current risk areas are land and water rights, gender inequality and low social capital. Sorghum does offer great possibilities to increase activity and income, create employment and improve livelihoods for all VC-actors, at all stages. The sorghum sector can only reach this potential if solutions are encountered for all the challenges identified and if risk mitigation strategies are in place.

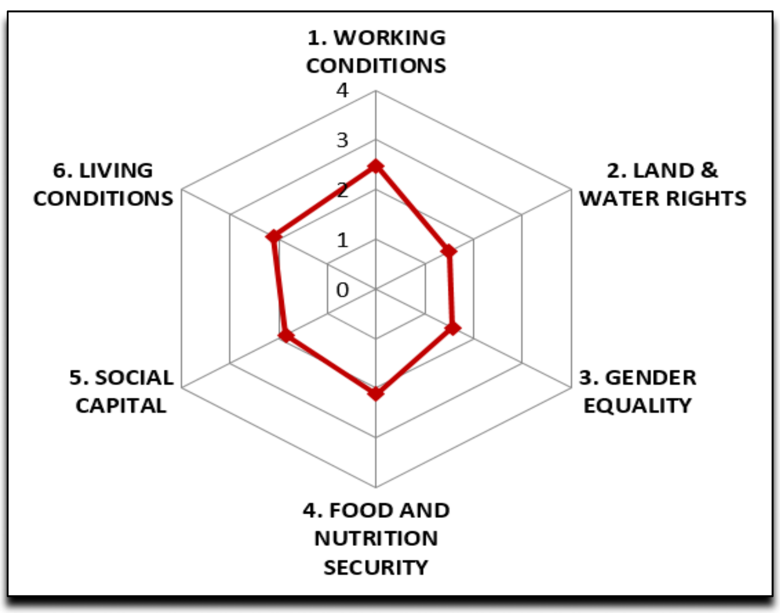

Figure 5-13 : Spiderweb diagram of six research domains of the social analysis
Source: Study

Table 5-5: Summary of key issues identified in the sorghum value chain

#	Area	Main issues identified
1	**Working conditions**	- Labour laws reflect international conventions, but enforcement is not strong. - Especially not for farm wage labour. No monitoring and control of working conditions, job safety by ministry of labour or ministry of agriculture. - Vulnerability of farm wage labourers employed by commercial farmers. - Working conditions at the industrial brewery seem favourable and attractive. - Working conditions for pito brewers are not very favourable. - No worker / labour associations or representatives for farm labour and pito brewers. - Low investment in vocational training limiting opportunities.
2	**Land & water rights**	- No land titles or formal regulation for investments (based on chief system, goodwill and personal relations and preferences). - Vulnerability to climate change and no climate smart agriculture, mitigation or resilience policies in place.
3	**Gender equality**	- Strong traditional role and task division between men and women - Women have no time have for leadership positions - No access to land and land title for women - Low to no decision power for women at production and expenditure level - Very challenging for women to get access to credit
4	**Food and Nutrition security**	- For the majority of VC actors food insecurity for approximately three months a year (June-August). - In the rural areas diets not very diverse yet and focus still on intake of kcal; fruits and vegetables not very available in the three northern regions. - Sorghum very nutritious crop but more considered as cash crop (the white variety). - The red (traditional) variety important nutritious food crop but underestimated. Missed opportunity, especially for children (considering the taboo on the unfermented 'pito').
5	**Social Capital**	- Lack of transparency, information in the VC, especially in terms of pricing. - Lack of horizontal and vertical trust between VC actors. - Power imbalances between the main formal offtakersand smallholder farmers. - Power imbalances between commercial farmers and SHF in input supply. - Lack of well organised farmer associations, representations and cooperatives; lack of one farmer voice. - Lack of effective lobby and advocacy sector platform and sector representative.
6	**Living Conditions**	- Access to and affordability of health care is a huge challenge in the rural areas - Housing is improving but at the rural remote areas very poor and traditional - Access to and affordability of electricity is a huge challenge in the rural areas (for those not living near the main road). - Primary and secondary schools are available, but accessibility and affordability is still a challenge in the rural areas. - Enrolment rates in primary education are high but the transition rate from basic to secondary education and from secondary to tertiary education is low.

5.4 Conclusions from social analysis

The value chain is socially sustainable and has the capacity to be increasingly socially sustainable.
Sorghum remains important in the food systems in the Northern Regions of Ghana and is therefore crucial in household food security. This is despite the fact that rice and maize have overtaken sorghum in terms of source of calories in most households, especially of smallholder farmers. It has a long history of being sold by smallholder producers, including SHF1 farmers, for transformation or processing into traditional pito (both the alcoholic and non-alcoholic beverages). Its prominence as a cash crop, offering opportunities for small-scale farmers, small businesses and entrepreneurs, has grown in recent years due to entry into the sorghum market by the industrial brewery as a major buyer using the grain for producing both alcoholic and non-alcoholic beverages. The positive impact of this engagement has not only been on large-scale aggregators and commercial farmers found in Sub-chain 3 but also on smallholder (SHF2 farmers) in Sub-chain 2. It has therefore triggered inclusive growth through creating space for the involvement of smallholder producers cultivating 2.5 hectares and below.

An interesting dimension of the recent developments in the sorghum value is that the emergence of the formal Sub-chain 3 has not resulted in downsizing of the less formal Sub-chains 1 and 2. This is partly because the market for the traditional pito remains big, one of the largest contributors of value added in the chain (as noted in the economic analysis in Chapter 4). The traditional pito-brewers remain very active and are unlikely to be squeezed out of the market because they utilise the red varieties of sorghum which is not preferred by the industrial breweries, thereby remaining a sustainable segment of the value chain.

Keeping young people involved in SHF2 would require alleviation of land tenure and inheritance impediments. Moreover, the majority of the workforce in jobs in the value chain is being employed on an informal, casual or temporary basis due to the variability of demand, this has implications for the terms of employment plus job and income security. There is a risk that the workforce struggles to earn a basic living wage and living standards will decline over time.

The sorghum value chain contributes to inclusive economic growth but is far below its potential.
Women in particular benefit from employment opportunities as they carry out most of the tasks associated with production and the traditional processing. Both, men and women gain a degree of financial independence from their involvement in the VC. Returns from small-scale production benefit the local economy and are invested in children's education, health care, housing, small businesses and in the farm. However, sorghum can contribute much more if the challenges identified are taken into account. These challenges are in the areas of: i) no effective smallholder farmer groups and power imbalances between VC-actors, ii) low farm labour wages and harsh working conditions at the pito breweries, iii) land tenure system, iv) gender inequality in terms of access to land and credit and low decision power), v) health care and affordability and investment in vocational training.

The detailed VCA4D Social Profile analysis can be found in Appendix 1. Table 5.6 below summarizes some mitigation measures per domain.

Table 5-6: Mitigation measures per social domain

Dimension	Mitigating measures
1. WORKING CONDITIONS	
1.1 Respect of labour rights	Requires strong efforts from the government on monitoring and enforcements of labour laws and regulations. Labour associations and worker representation could improve transparency.
1.2 Child Labour	
1.3 Job safety	Stronger awareness raising among farm labourers and preventive measurements (e.g. always first aid kit in the field, transportation means available in case of emergency). For the pito brewing process the more advanced systems (see photo report) decreases the harsh and dangerous work environment.

1.4 Attractiveness	Investment in vocational training at all stages in the chain; possibilities for access to credit.
2. LAND & WATER RIGHTS	
2.1 Adherence to VGGT	Awareness raising among smallholders to prevent them from selling their land. Enable smallholder to increase their acreage with sorghum. Also lobbying to clarify vulnerable position of smallholders in negotiating the price.
2.2 Transparency, participation and consultation	Via stronger and effective farmer organisations and cooperatives.
2.3 Equity, compensation and justice	Innovate in the sector to manage climate change; at the level of producers, but also at level of public goods. Requires strong position public sector or collaboration in the sector.
3. GENDER EQUALITY	
3.1 Economic activities	Higher participation of women in the VC may be promoted, but would require cultural shift as well; Facilitate access to credit and training for women.
3.2 Access to resources and services	Overall increase in property rights will help as well as access to credit through associations (if established).
3.3 Decision making	Promoting participation of women in technical capacity building. But also gain more insight into the desire of women to participate in the production process aside from domestic work, care for family and other income generating activities.
3.4 Leadership and empowerment	Higher participation of women in the VC may be promoted, but would require cultural shift as well
3.5 Hardship and division of labour	Very challenging, would require cultural shift, but also better services for women (e.g. day care)
4. FOOD AND NUTRITION SECURITY	
4.1 Availability of food	If smallholders are able to produce larger areas and are provided with credit to make agricultural inputs affordable, this risk is mitigated.
4.2 Accessibility of food	Increasing production, reducing cost increasing resilience, access to credit at the time of land preparation. Timely payment of produce sold.
4.3 Utilisation and nutritional adequacy	Education is needed. Probably, outside the scope of the VC. Increase and facilitate availability of more nutritious food items in the northern regions (vegetables and fruit). Facilitate promotion of non-fermented, non-alcohol pito for children.
4.4 Stability	Proper measures to manage climate change and diversify income portfolio and facilitate smallholders to increase acreage used for food and cash crops. (see above).
5. SOCIAL CAPITAL	
5.1 Strength of producer organisations	Capacity building of groups, cooperatives and associations. One voice stimulates power balance in the VC. Consider the option of a sector platform.
5.2 Information and confidence	Better organization of the sector and stronger involvement of the public sector. Establish a sector platform / lobby. Monitor monopoly position of the industrial brewery.
5.3 Social involvement	

6. LIVING CONDITIONS	
6.1 Health services	Improved production and efficiency, on-time payment; payment via bank accounts, discount or facilities for farm wage labourers. Improving health insurance system. Improve stocking of medical health care posts in the villages. Monitoring and control of the CHPS.
6.2 Housing	Through improved income, but also public efforts.
6.3 Education and training	Better organization of the sector and stronger involvement of the public sector may help

Source: Study

6 ENVIRONMENTAL ANALYSIS OF SORGHUM VALUE CHAIN

6.1 Introduction:

This chapter focuses on the environmental analysis of the sorghum value chain in Ghana. The analysis is based on the Life Cycle Assessment (LCA) methodology described by two ISO norms (ISO 14040 and ISO 14044), even though it was not possible to strictly comply with all the criteria contained the ISO norms. In the case of the sorghum value chain, the life cycle analysis encompasses the following main stages: extraction and production of all inputs – including those used for cultivation–, grains transportation and processing of grains into products for consumption. The analysis follows four steps, which are reported in four parts of this analysis:

1) Goal and scope definition;
2) Life Cycle Inventory (LCI);
3) Impact assessment;
4) Interpretation

6.2 Goal and scope of the environmental analysis

Given the lack of a complete and updated analysis of the sorghum value chain, EU/DEVCO, the EU delegation to Ghana and the MoFA have requested an analysis aimed at improving the understanding of the value Chain (VC) functioning and at providing a baseline for measuring future changes in the sorghum production by highlighting "the most relevant strengths, risks and opportunities in the value chain, the points to be further analysed in depth, and the aspects that are difficult to inform", as stated in the Terms of Reference (ToR) of the Sorghum Value Chain Analysis in Ghana. Therefore, the main purpose of the LCA analysis is to provide insights into the environmental sustainability of the value chain-under study in order to "support the Delegation of the European Union and their partners in improving policy dialogue, investing in value chains and better understanding the changes linked to their actions", as described in the Methodological brief (v1.2, 2018). Taking this into consideration, the framing question was tackled in the most exhaustive way possible, considering the time-frame of the study. The ReCiPe endpoint life cycle impact assessment method was selected in accordance with the indications of the EC/DEVCO – VCA4D Methodological brief. Indeed, this document breaks down the framing question, "*Is the VC environmentally sustainable?*" into three core questions, focused on the potential impact of the VC in terms of (1) resources depletion; (2) ecosystem quality, and (3) human health, which correspond to the areas of protection of the ReCiPe 2016 method.

To determine the level of environmental sustainability of the value chain (and its sub-chains), the following three main objectives were defined:

- To quantify the potential environmental impacts of the current sorghum value chains in Ghana, based on available knowledge;
- To calculate the contribution of the main stage of the life cycle for the main products and to highlight the environmental hotspots;
- To provide elements for discussion on the sustainability of the sorghum value chains in Ghana.

As reported in the ToR, sorghum is a multipurpose crop, important for food security provision and essential to provide cash for households. Sorghum brewing is an important cottage industry in northern Ghana, since malted sorghum grains are used to prepare the local alcoholic beverage known as *pito*. The crop has received sporadic and limited attention by policy makers, but recently, there has been a renewed interest in reinvesting in the product, particularly by the brewing industry, whose long-term objective is to replace barley malt, imported from other countries, with sorghum.

As a consequence, in order to explore the level of environmental sustainability of the value chain, the following secondary objectives were defined:

- To evaluate and compare at farm-gate the cropping systems identified, regarding four different groups of farmers, namely mainstream smallholders using no modern yield-enhancing agricultural inputs except mechanical ploughing (SHF1), emergent smallholders using a low level of external inputs estimated at about 20% of their requirements (SHF2), lead and medium-scale farmers (LMF) and commercial farmers (CF).

- To determine the environmental impacts of all types of products obtained from sorghum grains in Ghana, namely the three sub-chains (1) represented by artisanal *pito* –an indigenous sorghum beverage brewed on household basis as well as milled grains for rural household consumption, (2) represented by semi-industrial small-scale sorghum beer[31] and also milled and packaged grains for urban household consumption and (3) beer at industrial scale using a blend of sorghum grains and barley malt [32]. In addition, brewers spent grain from brewing pito and beer is also sold mainly to farmers rearing pigs.
- To compare business-as-usual and alternative scenarios for the sub-chains of sorghum-based products with the purpose of providing insights on how potential evolutions of the sorghum value chain may affect its environmental performance. In particular, comparisons regarded a best-case scenario of improved agricultural yields [33] along with a comparison between (1) industrial sorghum-and-barley beer production and (2) a benchmark scenario of 100% imported barley malt beer production. The latter provides insights for industrial breweries interested in entering the sorghum value chain in the near future. These scenarios will be explained in detail in section 6.3.3 (see Table 6.2).

It is possible to compare the results of the analysis for only two of the three types of products: the small-scale sorghum beer production and the industrial scale sorghum-and-barley beer production, whereas a formal comparison between beer and *pito* cannot be carried out, since their characteristics and their end-markets are not comparable. As for their main characteristics, *pito* is an artisanal product with variations in quality (Zinia Zaukuu et al, 2016), and it is intended for consumption within maximum 3 days since production, while beer is produced through standardized processes and it has a long shelf life. This leads to a difference also in end-markets, because the requirement of consuming *pito* while still fermenting prevents long distance transport or large scale distribution, with the result that *pito* cannot substitute beer in areas where it is not produced; on the contrary, in most areas where *pito* is produced, beer is also available.

The geographical coverage of the study is defined in Chapter 1 and focuses on the regions where production of the crop is concentrated (Northern, Upper West, Upper East, Savannah and North East). Since processing of sorghum takes places also in other areas of the country, the spatial coverage is national.

6.2.1 Systems boundaries

Given the objectives of this analysis, the sorghum value chain was modelled according to the main phases: cultivation of grain sorghum, transport of grains to the storage facility where cleaning, grading and storage operations are carried out, transport to the pre-processing site (malting and/or milling of grains) and processing (brewing of beer and *pito*). Since *pito* is brewed and in most cases also retailed on household basis at the brewing site, the system boundaries for all types of products investigated were set from cradle to brewery gate, also considering the fact that sorghum products in Ghana are intended for the domestic market alone. In the case of *pito*, the brewing site gate corresponds also to the downstream (retail and use), while in the case of beer the downstream phases were not included in order to have a common system boundary throughout the study. It is worthwhile to keep in mind the limitations and cautions about comparisons between *pito* and beer sub-chains, as well as the constraints due to data availability and time-frame of the study.

Figure 6.1 shows the main phases of the full sorghum value chain and its by-product. Regarding the environmental impact of grain-milling alone, it will be also discussed in the results section. This process is identical to that of the early stage of the brewing process in which grain is milled. Since the milling operation has a very low energy consumption, the environmental impacts associated to it are negligible. Therefore, as it can be expected, all relevant impacts of milled grains derive from the cultivation stage, for which detailed results are presented.

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[31] *microbreweries produce 100% malted sorghum beer.*
[32] *to date, no industrial brewery produces beer from sorghum alone.*
[33] *yields were simulated at the level of national potential of 2.0 t/ha for SHF2 (10,000 farmers out of 47,000)..*

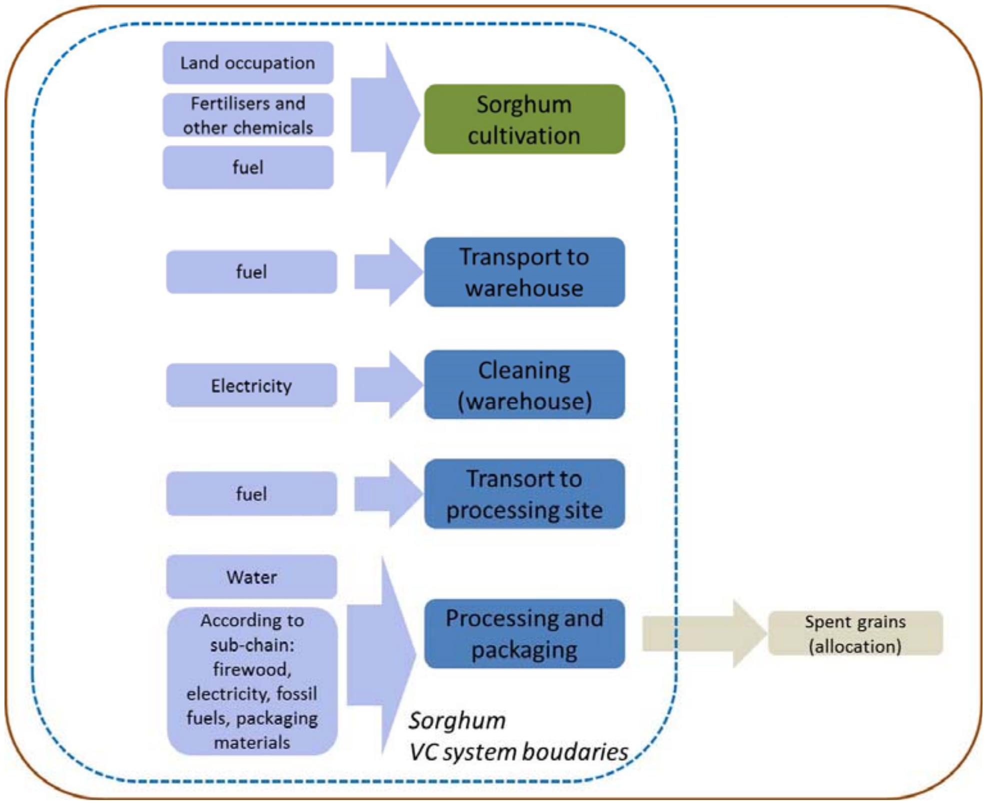

Figure 6-1: System boundaries from cradle to gate of the sorghum value chain in Ghana.
Source: Authors

The analyses encompasses the production of all the key inputs, their use, correlated emissions and transportation at the different VC phases, while infrastructure was excluded, except for tractors and trucks. Inputs and outputs of processing phases are described below, according to the sub-chain and product.

6.2.2 Studied value chain and functional unit

The value chain, which falls completely within national borders, is divided into three main sub-chains, which are briefly described in Section 3.2.1 and consists of the following:

- Sub-chain 1 in which exclusively malted sorghum grain is used for artisanal *pito* brewing and the rest as milled grain for rural household consumption for which results are not displayed, as explained in the above paragraphs);
- Sub-chain 2 which also supplies grain for pito brewing but also for semi-industrial malted sorghum beer brewed by microbreweries, using exclusively malted sorghum as well as milled grain for urban household consumption for which results are not displayed, as explained in the above paragraphs);
- Sub-chain 3 in which occurs industrial brewing of beer from a blend of sorghum and barley malt.

The first two sub-chains, 1 and 2, rely on grain production by two types of smallholder farmers, those using no inputs (SHF1) and others using low levels of external inputs (SHF2). Supply of sorghum grain for industrial brewing chain is from SHF2, lead and medium-scale farmers (LMF) and commercial farmers (CF). The production processes for the three main brewery products in the sorghum value chain are shown in Figures 6.2, 6.3 and 6.4 below.

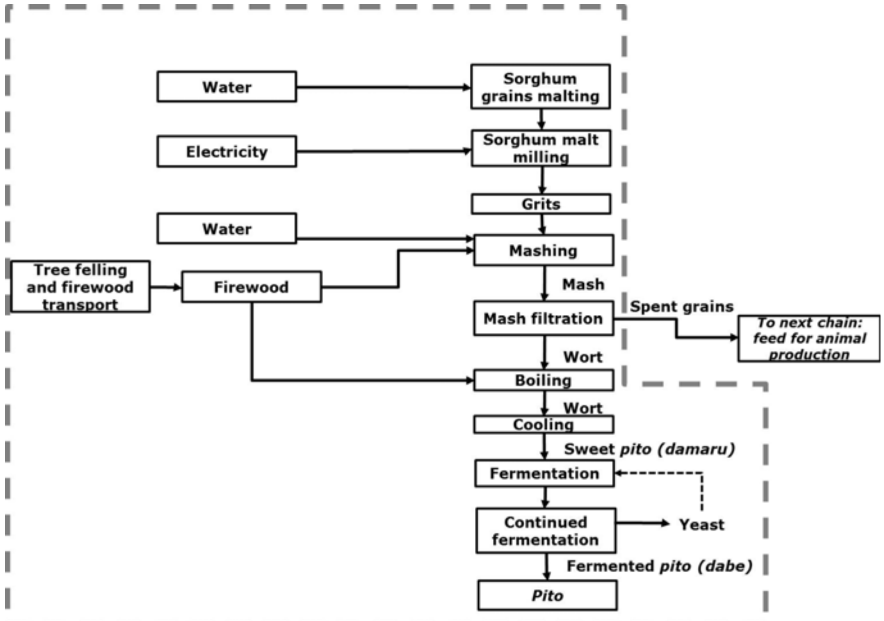

Figure 6-2: Pito brewing (from sorghum grains malting to pito production)

Source: Authors

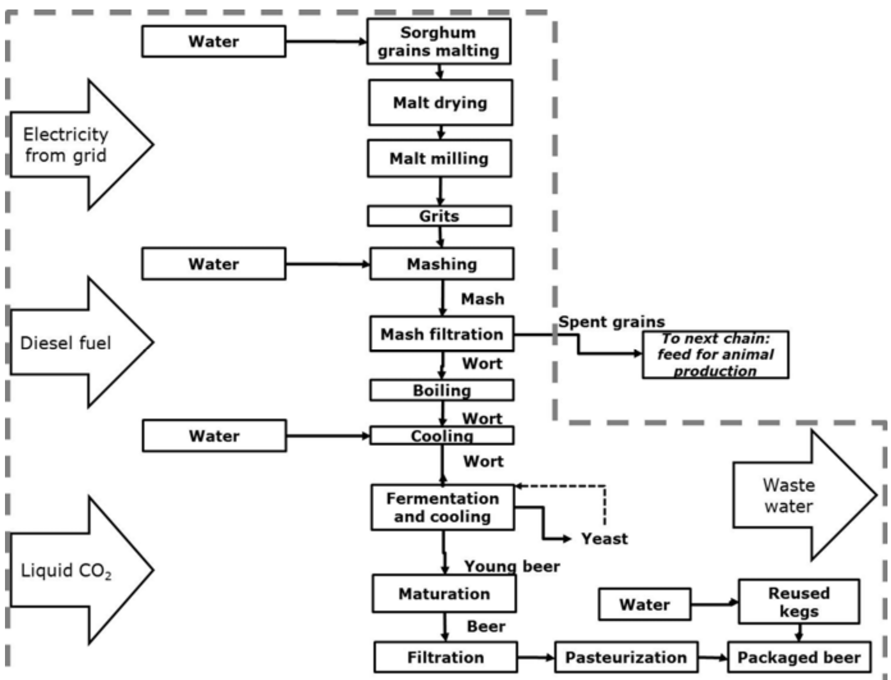

Figure 6-3: Process for microbrewing (from sorghum grains malting to beer packaging in kegs)
Source: Authors

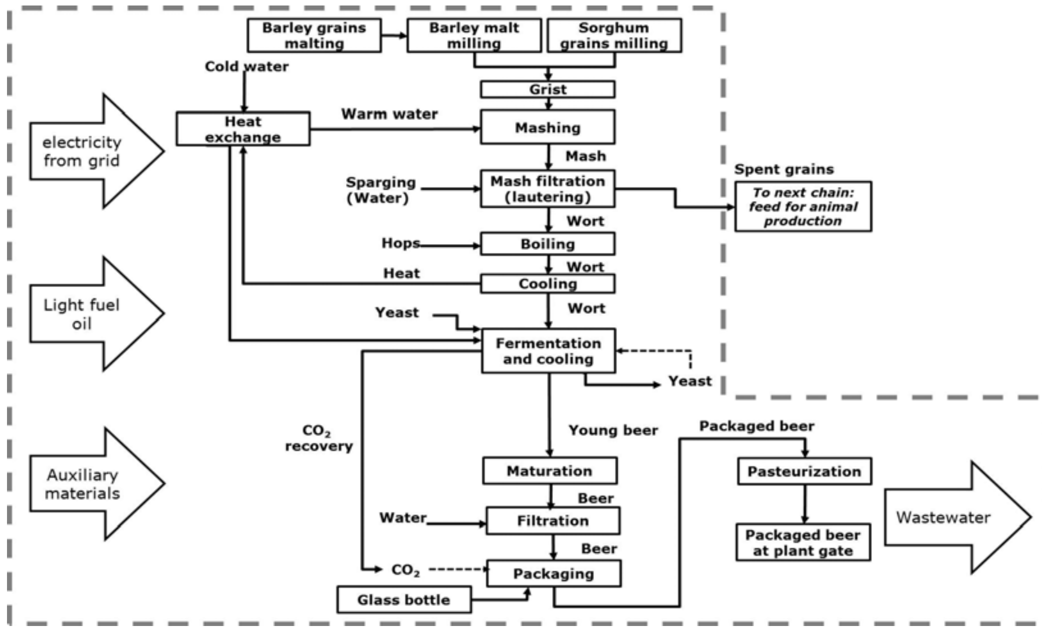

Figure 6-4: Industrial breweries (from barley malting and grains milling to beer packaging in glass bottles
Source: Authors

The pre-brewing process involves malting and milling, whilst the brewing process generally requires malted or a mix of malted and non-malted milled grains. They are carried out in different ways depending on the sub-chain and are briefly described below:

Malting: Germination follows the steeping process (soaking grains in water, increasing moisture from 12% to around 45%) and in the case of the *pito* sub-chain occurs in a thin layer on a solid floor. However, moisture has to be reduced and the germination activity stopped, which is achieved by simply heaping-up the grains so that the heat released by the germination stops the process: this operation is called kilning. In a modern malting facility kilning is automated and carried out by heating the germinated grains using electric power or fuel. After steeping, germination takes place on a floor that is slotted to force air through the grain bed, so that heat and moisture levels are kept under control. The moisture of malt after kilning is around 12% in the case of the traditional malting processes, while in a modern malthouse it is possible to reach a 4% moisture content, allowing long periods of malt storage.

Milling: A coarse grain flour called grits is obtained by milling the malt. The purpose of this operation is to break apart the kernels and expose the cotyledon, which contains the majority of carbohydrates and sugars; this makes it easier to extract the sugars during the mashing.

Mashing: This is the first step of the brewing process, in which grits are mixed with water. Mashing consists in a hot water steeping process during which the starchy content of the mash is hydrolysed, producing a liquor called sweet wort. In the mashing process, hot water between 71 and 82°C is used to increase the efficiency of wort extraction.

Mash filtration: In this phase, following the completion of the mash conversion, the wort is separated from the mash. The extracted grain, termed “spent grain” is most often used as livestock feed.

Wort boiling: Boiling sterilizes the wort, coagulates grain protein, stops enzyme activity, drives off volatile compounds, causes metal ions, tannin substances and lipids to form insoluble complexes, extracts soluble substances from hops and cultivates colour and flavour. It is the most fuel-intensive step of the brewing process (Olajire, 2012). Indeed, in the case of the *pito* sub-chain, the requirement of firewood for boiling is very high.

Wort cooling: In an industrial and semi-industrial brewing process, the boiled wort is clarified through sedimentation, filtration, centrifugation or whirlpool before cooling, which occurs by means of water cooling systems based on heat exchangers. In the *pito* brewing process, cooling takes place overnight.

Fermentation: Once the wort is cooled, the fermentation process can take place. During fermentation, the yeast metabolizes the fermentable sugars in the wort to produce alcohol and carbon dioxide (CO_2). At the end of the fermentation process, which takes 2-3 days, the yeast rises to the surface forming a foam that is skimmed off, re-cultivated and used several times. *Pito* is retailed at this phase, during fermentation.

Maturation: Beer aging or conditioning is the final step in beer production. The beer is cooled and stored in order to settle yeast and other precipitates and to allow the beer to mature and stabilize. The beer at this stage is cooled to temperatures ranging from -1 to 10 °C.

Filtration: In industrial breweries a kieselguhr (diatomaceous earth) filter is typically used to remove any remaining yeast.

Packaging: Beer is usually packaged in glass or PET bottles, aluminium cans or steel kegs. The packaging formats considered in this analysis are glass bottles and kegs, since beer is normally retailed in these formats in Ghana. In particular, commercial breweries retail their products mostly in 625 ml glass bottles, while in the case of microbreweries, the format is a 18 L returnable steel keg. As previously mentioned, *pito* is mostly retailed unpacked at the brewing site, where it is served in calabashes, therefore no packaging was foreseen for this sub-chain.

Pasteurization: Before being packaged in kegs or once it has been packaged in bottles, beer must be cleaned of all remaining harmful bacteria, which, especially in the case of a beer that is expected to have a long shelf life, is achieved through pasteurization, the process of heating beer to 60 °C to destroy all biological contaminants. After this final operation, the packaged beer is ready for distribution at factory gate.

In the environmental analysis, the functional unit (FU) used for all the products is one (1) litre (L) and its packaging (where applicable) at brewer's gate. Therefore the FU for pito is 1 L; and is the same for beer from microbreweries as well as industrial breweries.

6.2.3 Data sources

The Life Cycle Inventory (LCI) of the environmental assessment was built on the following data:

- Primary data: data and information collected during the field missions through interviews with key informants representing various segments in the value chain (1°: 19 May – 1 June 2019; 2° 29 September – 12 October 2019) and through a field surveys conducted in October 2019 with the support of local enumerators as reported in Table 1.2. Primary data was used for the sorghum cultivation phase and for processing of sorghum grains into *pito* and beer (MB). In particular, for the cultivation stage, data was derived from interviews held with aggregators, lead and commercial farmers representing over 4,000 smallholder farmers (Table 6.1 in section 6.3.1);
- Secondary data: material and information provided by MoFA, SARI, GIZ, EPA, national statistics. Modelling of sub-chain 3 was based on lite rature data because primary data regarding the industrial brewing sector remained undisclosed. Since this sub-chain is based also on imported malted barley, cultivation of barley and malting process were modelled using data derived from literature and LCI databases. For the background data, LCI databases, namely Ecoinvent (version 3), Agribalyse (v 1.3), Agrifootprint database and USLCI were used.

6.2.4 Data quality and main limitations and assumptions

The main assumptions of this study are strongly linked with its main limitations. Indeed, the impossibility of collecting primary data from the industrial brewery led to the compilation of a generic life cycle inventory (LCI) of the malting and brewing stages of the beer produced with an industrial process. Therefore, the inventory was based on literature data, which are applicable to any industrial brewery that carries out a standardized brewing process without on-site energy generation[34]. In general, the inventories of the three sub-chains are based on information provided mostly through oral communications from memory recall by farmers and brewers, which could lead to inaccuracies. An exception to this is detailed data collected through interviewing the master brewer in charge of a microbrewery, who first introduced a standard process of sorghum beer production in Ghana. The data he provided is assumed to be adequate for the case of industrial-scale brewing. This person also provided key information on the two other sub-chains (sub-chains 1 and 2).

An assumption was made in terms of carbon stock loss due to land use change triggered by firewood extraction for *pito* brewing. From the information gathered (see Appendix III), firewood extraction leads to a degradation of forests, therefore a land transformation was associated with the firewood used for *pito* brewing.

Throughout the study, assumptions regarded typical transport distances, as well as typical moisture content of sorghum grains. Assumptions also regarded moisture of the co-product (spent grains), and a standard price of this material for allocation purposes. In this regard, the only robust data were provided by for the case of the microbrewery and it was used for the allocation on the co-products. Nevertheless, according to the demand, prices of spent grains might vary.

Also a complete characterization of wastewater from malting and brewing is missing (only data on COD –Chemical Oxygen Demand– and Phosphate for wastewater from breweries was available). This might lead to underestimations of the impacts due to discharging wastewater, which in the case of sub-chain 1 and sub-chain 2 is untreated.

6.3 Life cycle inventory

The three sub-chains products investigated in this analysis share the following (Figure 6.5):

- Sub-chains 1 and 2: sorghum cultivation by SHF1 and SHF2; and
- all sub-chains: sorghum grains cleaning, sorting, grading and storage at warehouse.

Regarding the non-agricultural upstream phases and the core (brewing) stage, although the malting, milling and brewing operations are common to the three sub-chains, these are carried out in different ways in each sub-chain, therefore they are considered separately. The data used for the LCI of each life cycle stage are detailed below.

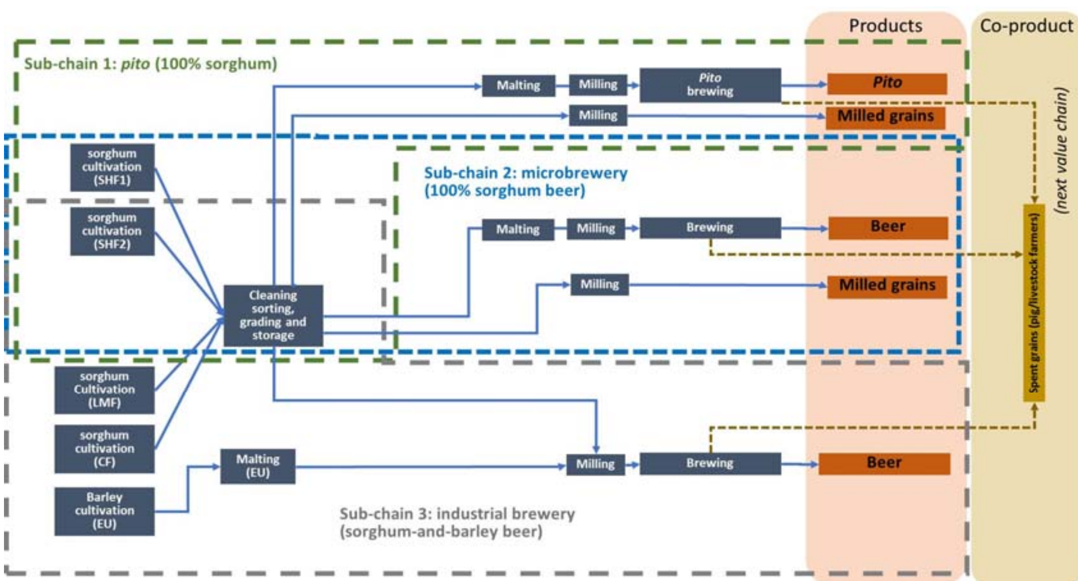

Figure 6-5: System boundaries of the 3 sub-systems (showing common and differentiated phases)

Source: Authors (modified from Figure 3.1 in Chapter 3)

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[34] *On-site energy generation (i.e. through anaerobic digestion facilities fed with spent grains from the brewing process) may lead to drastic improvements in the energy efficiency and therefore the overall environmental performance of the brewery.*

6.3.1 Sorghum cultivation

Sorghum is an annual cereal crop widely cultivated in northern regions of Ghana, where about 97% of production is concentrated. Production is rainfed and mainly based on manual operations. Through the interviews conducted during the field missions, it was possible to identify four main types of farms cultivating sorghum, on the basis of their dimension and organization. These interviews allowed also to define the main agricultural practices and characteristics of the different types of farms, in particular in terms of agricultural input levels and grain yields. The total number of farmers represented by the interviewees was over 4,000 (Table 6.1). LCI data for cultivation was derived mainly from these interviews and supported by the surveys conducted by external technicians on behalf of the analysts in October 2019, which represented further 30 individual farmers.

Table 6-1: interviews held in May and October 2019 and number of farmers represented

Location	Meeting with	Number of farmers present at meeting	Number of smallholder farmers supported/represented
Wa	Farmer and certified seed producer	1	600*
Sabuli district (Wa)	Lead farmer	32	6 groups of farmers
Wa	Aggregator	1	1200
Wa	Input dealer / support provider	none	300**
Wa	Farmer and aggregator	1	850
Nyole community (Wa)	Farmers groups	15	31
Gindabuo community (Wa)	Lead farmer	12	450
Kpongiri community (Wa)	Farmers groups	32	90
Kaleo community (Wa)	Commercial farmer	1	120
Daboya (Savannah Region)	Commercial farmer	1	600

*farmers receiving technical support from certified seed producer.

**farmers receiving technical support from input dealer.

The types of farmers identified can be classified into two main groups 1) smallholder farmers and 2) lead, medium-scale and commercial farmers. They have the following main characteristics:

1) Smallholder farmers, which are further subdivided into the following categories:

- Smallholders using no agricultural inputs (SHF1): this category includes farms having no access to external inputs except mechanical ploughing; farmers retain part of the grain production as seeds for the following year sowing. Average yield of this category of farmers (0.65 t/ha) is significantly lower than the national average (1.2 t/ha[35]).
- Smallholders using low levels of agricultural inputs (SHF2): they typically apply inputs (fertilizers and herbicides) to 1/5 of the cultivated area. This happens because aggregators can normally meet their requirements for only one fifth of the cultivated area. For this reason, the external inputs attributed to SHF2 are on average 20% of the required levels. Like in the case of SHF1, propagation materials are grains retained from the previous harvest. Average yield for this category is 0.85 t/ha.

Smallholders sorghum grain yields are generally low[36], mostly due to management problems such as low rate of adoption of appropriate crop rotation schemes, low plant populations, inappropriate sowing time, inadequate control of weeds, pests and diseases. Other production constraints at farm level include not only a limited access to land and water resources, or the scarce availability of labour, but also the inadequacy of drying and storage facilities, which generally leads to high post-harvest losses. All these factors are to be considered as common problems for any smallholder farmer. Further issues are related to the low purchasing power of smallholder farmers and to the limited availability of fertilizers that contributes to the general nitrogen deficit condition under which sorghum is cultivated. In particular, problems of lack of inputs and lack of credit that some smallholder farmers experience at different levels determine much of the differences in terms of the input use and input use efficiency characterizing smallholders' farming.

2) Medium-scale and large farmers adopt improved agricultural practices that include the use of external inputs at the required levels and higher mechanization levels, and cultivate improved varieties, dedicated to the industrial brewing provision chain. They are:

- Lead and medium-scale farmers (LMF) have an average yield of 1.8 t/ha. They use external inputs at the required levels, including improved seeds, they also carry out mechanical ploughing and threshing (for

[35] *Agriculture in Ghana –Facts and Figures (2017) Ministry of Food and Agriculture, Statistics, Research and Information Directorate (SRID), October 2018.*

[36] *Actual average yields correspond to 60% of the potential; national potential yield is 2.0 Mt, while national average yield was 1.2 Mt according to Agriculture in Ghana - Facts and Figures 2017 (MOFA-SRID, October 2018).*

50% of the production). Furthermore, lead farmers facilitate delivery of inputs as well as access to tractor services to SH on credit.

- Commercial farmers (CF): four commercial farmers produced sorghum in the country in the 2019 crop season. They cultivate improved varieties (Kapaala/Dorado) for beer brewing alone and therefore they supply exclusively to sub-chain 3. The two CF that were visited rely mainly on SH farmers for their supply to sub-chain 3. Therefore, although the overall agricultural areas of their farms range from 200 to more than 1,000 hectares. Also commercial farmers are involved in facilitating delivery of inputs to SH as well as access to tractor services. Apart from using inputs at the required levels, these farmers carry out most mechanical operations, namely tillage by cross-ploughing (two passages) and harrowing, sowing (over 50% of the cultivated area is mechanized) and threshing (for 80% of the production), while harvesting is manual. Average yields are the highest (2.5 t/ha).

For all categories of farms, it was considered that land cover prior to cultivation was fallow land or previously cultivated. In many cases land clearing is carried out before cultivation, but it is generally described as land preparation for cultivation of a long-term fallow area. In all known cases land clearing was carried out manually.

Ploughing is the only agricultural mechanical operation that is common to all types of farms, where a light ploughing (10 cm depth) is carried out. The estimated diesel consumption for ploughing one hectare is 10 L/ha.

As for threshing, it is partially mechanical in the case of lead, medium-scale and large farmers (LMF and CF), while other mechanical operations (harrowing and sowing) are carried out only by CF. Harvesting is manual in all cases.

Seeding rates vary according to the grains variety. On the one hand LMF and CF, supplying sub-chain 3, use certified seeds of the improved varieties at the rate of 10 kg/ha[37]. On the other hand, higher seeding rates are necessary (30 kg/ha) for local varieties[38]. In this case the propagation material is originated from the previous season, but the quality of the grain used as propagation material is rather low, which leads to low grain yields. Although cultivation of improved varieties is starting to spread among some SH farmers, the business-as-usual scenario for smallholders involves sorghum landraces cultivation. Sowing takes place at the beginning of the rainy season, in the month of June.

Regarding the use of fertilizers, SHF1 farmers do not fertilize at all, as they cultivate mainly landraces which are considered capable of producing without external inputs. Local varieties in general are perceived as being particularly climate-resilient, with the advantage of performing relatively well under conditions of marginal rainfall and high temperatures. As mentioned previously, SHF1 use external inputs at 20% of the required levels, while all other categories of farmers use the required quantities per hectare, which are:250 kg of tertiary fertilizer (15-15-15) and 125 kg of Ammonium Sulfate (SOA, 26.3 kg N). There is no evidence of any use of manure on the areas cultivated with sorghum.

Weeds are one of the main problems in the cultivation, since they may compromise the yield of the crop due to a strong competition for nutrients and water. Weed management in sorghum cultivation is carried out manually (by SHF1) or by means of an herbicide treatment (applied to 20% of the cultivated areas by SHF2, and to 100% of the areas of all other types of farmers).

Sorghum harvesting takes place in September/October, towards the end of the rainy season. The panicles are harvested when grains reach maturity, while the standing biomass is left on the ground. Panicles are then sun-dried on an open, clean area until they reach the moisture for storage, which is around 12%. Rain patterns greatly affect not only the cropping season, but also the harvesting and post-harvest operations; around harvest time it is essential that the dry season sets in, which is not always the case. The use of tarpaulins for grain drying can help to ensure reductions of post-harvest losses especially when the dry season does not set in at harvest time, but they are often not available to the farmer.

[37] *According to the certified seed producer interviewed, the inputs level for seed production is the same as that adopted by LMF. Seed production was modeled using the LCI for LMF.*

[38] *Production of retained grains used as seeds were modeled using the LCI of the corresponding type of farmer.*

With regard to the estimate of direct field emissions, N_2O emissions (direct and indirect), NH_3 and NO_3 emissions from nitrogen fertilization and of phosphorus due to erosion and phosphate due to run-off were included in the analysis.N_2O emissions are related to the amount of nitrogen supplied to the soil through nitrogen fertilization and to crop residues. The estimate of direct N_2O emissions is calculated as the product of such amount of nitrogen and the N_2O emission factor provided in the IPCC 2006 guidelines. The single estimation of the amount of nitrogen from crop residues in the aboveground and belowground biomass took into consideration the grain yields for each category of farm, and was based on the IPCC equation 11.7A (Vol. 4, Chapter 11) "Alternative approach to estimate FCR (using Table 11.2)", which allows to calculate the annual amount of N in crop residues for cereal crops (kg N/yr).

NH_3 volatilization from synthetic fertilisers and both indirect N_2O emissions from NH_3 volatilization and from NO_3 leaching/runoff due to nitrogen fertilization were also calculated based on the IPCC 2006 guidelines.

Phosphorus and phosphate emissions were calculated using the approach developed by Nemecek and Kagi (2007). Thus, for phosphorus emissions to water the following was considered:

- Leaching of soluble phosphate to groundwater (phosphate to ground water): since there is no use of slurry in sorghum cultivation, for this emission the default value of 0.07 kg P ha^{-1} $year^{-1}$ was used.
- Run-off of soluble phosphate to surface water (phosphate to river): it considers the default value for arable land corrected for the amount of P input to soil from mineral fertilizer, slurry and manure. Only mineral fertilizer was considered for sorghum cultivation.
- Erosion of soil particles containing phosphorus (phosphorus to river): this emission refers to the quantity of soil eroded, the P content in soil eroded, an enrichment factor and the fraction of eroded soil that reaches the river. The quantity of soil eroded (S_{er}) was calculated specifically for Northern Ghana, and it was estimated multiplying potential soil loss by the crop management factor (0.073 for sorghum), using values provided by Diao and Sarprong 2007. The quantity of soil eroded specific for Northern Ghana was calculated from values reported in the report of the IFPRI (2007) "Cost Implications of Agricultural Land Degradation in Ghana"[39], averaging the values for Northern and Upper West regions to a final value of 415 t ha^{-1} yr^{-1}.

Estimations of field emissions are reported in the Life Cycle Inventory of sorghum cultivation for each group of farms, on hectare and on ton of grans basis (Appendix II). In appendix III energy inputs of the three sub-chains, including assumptions regarding firewood extraction and its impact on land use change are reported, while appendix IV shows the LCI of non-agricultural upstream phases (from cleaning and storing of grains to milling) and of the core brewing phase, along with the transport distances assumed.

6.3.2 Cleaning, sorting and grading at warehouses

After harvest and threshing, farmers package and store the grains until commercialization, normally in 100- kg bags. The yields at farm gate are calculated after some manual cleaning.

Grain cleaning and grading machines are operated with diesel generators or electricity. Grid electricity consumption was derived from data obtained at the Wa warehouse. At warehouse, after grain cleaning, sorting and grading a loss of 3% was calculated from data gathered at a facility visited in the Wa area. Storage of grains may require re-packaging grains in bags of a different size from those used by farmers for packaging. Indeed, in particular grains for sub-chain 3 are packaged in 50-kg bags, as observed in the Wa facility. Storage and the involved operations were the only non-agricultural upstream phase common to all sub-chains, as mentioned previously. Operations in this phase is completely manual in sub-chains 1 and 2, while they are mechanical (using electricity) in sub-chain 3.

6.3.3 Pre-processing and processing

Data for the non-agricultural upstream phases (malting and milling of grains/malt) and the core phase consisting in the brewing and packaging operations were collected, where applicable, for sub-chains 1, 2 and 3 respectively from:

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[39] *International Food Policy Research Institute, 2007. Cost Implication of Agricultural Land degradation in Ghana. An Economywide, multimarket model Assessment. IFPRI Discussion Paper 00698.*

- *pito* brewers located in Accra, Tamale, Tema and Wa, where surveys were carried out. Detailed information were gathered from one *pito* brewer located in Tamale and two *pito* brewers located in Wa, where two typologies of breweries were visited: one using an open-fire structure and one using an improved technology for the mashing and boiling phases, consisting in firewood fueled ovens. Data gathered from the former were used for inputs (water and ingredients) and energy consumption estimations, while data collected from the latter allowed to estimate lower levels of firewood consumption determined by the use of ovens (up to 50% of the open-fire system). Brewing sites with open fires and using the oven technology are shown in Figure 6.6. The oven system for brewing is not widespread in Ghana, so there is a large potential impact of upscaling the adoption of this technology to the large number of *pito* brewers currently using open fire systems.

  Within the *pito* sub-chain, also data regarding malting and milling operations was collected in Wa, where a traditional malthouse was visited. The LCI also included secondary data from literature, such as the quantity and quality of untreated wastewater from sorghum malting and brewing, which within the *pito* processing is discharged in the nearest water body or waterway.
- sub-chain 2 is represented by a microbrewery located in the Accra area, which uses exclusively malted sorghum and retails with a packaging format consisting in steel kegs, which are reused. The microbrewery has a yearly production of 20,000 litres of beer. Detailed data and information about all types of brewing processes (from *pito* to industrial-scale beer production) were obtained through interviews with a credited expert in sorghum brewing technologies, the brewmaster in charge of the microbrewery. As also in this case untreated wastewater is discharged, estimations on untreated wastewater quantity and quality from sorghum malting and beer brewing at microbrewery scale were derived from literature.
- sub-chain 3 was modelled using mainly literature data, since as mentioned previously, none of the commercial breweries involved –or expected to be involved in the short term– in the sorghum value chain agreed to disclose information. Therefore, an extensive literature review was carried out, comprising scientific papers, public environmental declarations of the beer sector and book chapters.

  Values for key inputs (water, fuel, electricity, beer ingredients) are specific values from literature, in line with industry-wide averages. Indeed, figures from literature were checked for consistency not only against the Guidence Note for establishing BAT in the brewing industry (The brewers of Europe, 2002), that provides typical resource consumption values, but also against the report by Donoghue C. et al, 2012 (The Environmental Performance of the European Brewing Sector) that provides average data on water use, energy and greenhouse gases, secondary products, waste, wastewater, and packaging.

  The LCI obtained in this way is deemed to reflect the largely standardized processes that generally are in place in industrial breweries. Nevertheless, some breweries have incorporated highly efficient energy recovery facilities, such as anaerobic digesters producing biogas from spent grains and spent yeast, and generating energy, thus reducing the use of external sources of heat and power.

Since the model for sub-chain 3 based on secondary data, it was preferred not to include aspects such as specific energy and other resources reduction strategies that might be in place.

So, the LCI for this sub-chain in a plant without on-site power generation must be seen as a feasible scenario of 1) barley malt production outside Ghana and its transport into Ghana; 2) sorghum grains production in Ghana; 3) beer production from barley malt and sorghum grains. Nevertheless, it was assumed that systems of energy and water recovery through heat exchangers were in place, along with systems for completely recovering CO_2 from fermentation, since these systems are rather common in most industrial breweries. Besides, for glass packaging production, it was hypothesized the use of recycled glass from cullet, which actually reflects the situation in Ghana, according to the information gathered. Indeed, beer from industrial breweries in Ghana is generally retailed in 625-ml glass bottles, partially produced with recycled material (cullet). It was shown that in the beer industry, packaging greatly affects the environmental impacts of the product (Cimini and Moresi, 2016, Cordella et al, 2008, Hospido et al, 2005, Koroneos, et al 2005 and several Environmental Product Declarations EPD®: *Carlsberg®* 2016, *Tuborg®* 2016, *Angelo Poretti®* 2016, *Kronenbourg®*, 2016). For this reason, a key factor is the inclusion of a share of cullet use in the simulation of packaging production.

Figure 6-6: Upper left: pito brewing site (oven type), upper right: firewood necessary for brewing 400 L of pito in an open-fire brewing site, below: open-fire brewing site.
Source: Authors

A further simulation within this sub-chain regarded the use of barley malt alone for brewing beer. This scenario was elaborated in order to provide insights into how the use of sorghum as raw material for brewing may affect the environmental performance of an industrial brewery shifting from the use of barley as main raw material to the use of sorghum. Indeed, an estimation of the environmental implications of such shift might be interesting for industrial players intending to enter the sorghum value chain in the near future.

The evaluated sub-chains, together with the above-described scenario and the best scenario of sorghum cultivation across all sub-chains (*Best Scenario of Sorghum Farming-BSSF*) are shown in Table 6.2. For the BSSF scenario, it is supposed that 10,000 producers of the SHF2 category will access the same input level of inputs as LMF, which comprises the following: use of improved seeds (10 kg/ha), NPK: 250 kg/ha; SOA: 125 kg/ha, mechanical ploughing, 50% mechanical threshing. It is also assumed access to extension service, which along with the correct level of inputs would lead to obtaining the attainable yield for sorghum (2.0 t/ha[40]). Furthermore, in this scenario, it is simulated an improvement in post-harvest management, in particular through the use of tarpaulins for grain drying, so that post-harvest losses are reduced, resulting in an increased average farm-gate yield.

This scenario was simulated in order to provide further insight regarding the effects of possible widespread, in the mid-term, of improved agricultural practices, leading to improvements in yields, as discussed in sections 2.3.1 and 3.2.1. In particular, sub-chain 2 and 3 would be affected by BSSF. In sub-chain 2 it is assumed that grain supply would shift from SHF1/SHF2 to SHF2 with improved yield alone. In sub-chain 3 it is assumed that supply would shift from SHF2/LMF/CF to a mix of grains produced by SHF2 (business as usual), SHF2 (improved yield), LMF and CF.

[40] *MOFA, 2018. Agriculture in Ghana- Facts and Figures (2017). Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture (October 2018).*

Table 6-2: Scenarios for each sub-chain comprising business-as-usual, best-case and benchmark

Sub-chain	Type of scenario		
	Business-as-usual (BAU)	Best-case (BC)	Benchmark
1	Sub-chain 1, supplied by SHF1 and SHF2	Sub-chain 1, supplied by SHF1, SHF2 (50% firewood)	-
2	Sub-chain 2, supplied by SHF1 and SHF2	Sub-chain 2, under BSSF (SHF2, 100% inputs/improved yields alone)	-
3	Sub-chain 3, supplied by SH2, CF and LMF	Sub-chain 3, under BSSF (improved yields of part of SHF2, all other farm types unchanged)	Sub-chain 3, brewing with barley malt alone

For sub-chain 3 a mix of 70% sorghum grains and 30% barley malt was assumed. A cut-off was applied to inputs used in negligible quantities. This is the case of yeast, which is normally reused for a number of generations within the brewery and for which, according to the technology, input quantities vary largely in industrial breweries (i.e. 21 g/L according to Amienyo and Azapagic, (2016), 45 g/L according to Sipperly et al (2016), without considering reuse). The cut-off also regarded hops, used at a rate of 7 mg/L beer (Cordella et al, 2008), and which according to Amienyo and Azapagic (2016), contributes to 0.3% of the GWP of raw materials and auxiliaries in beer production.

6.3.4 Co-products

The use of spent grains as animal feed, in particular in pig farming is widespread in Ghana. The demand for this feed is therefore high, so an economic allocation was used in order to attribute part of the environmental burdens to this co-product. Allocation to spent grains for sub-chains 1, 2 and 3 are 2.2%, 0.36% and 0.19% respectively. These decreasing allocation percentages for sub-chains 1, 2 and 3 are due to the differences in price at brewery gate of *pito* and beer (pito<beer-microbrewery<beer-industrial) and to differences in terms of mass of spent grains generated (beer-industrial<beer-microbrewery<pito, as shown in Table 6.9, core phase, "spent grains"). In Figure 6.7 spent grains at a pig farm visited by the team.

Figure 6-7: Spent grains (co-product of the brewing process used by pig farmers as feed)
Source: Authors (Kumasi outskirts, May 2019).

6.4 Results: life cycle impact assessment

6.4.1 Life cycle impact assessment method

The ReCiPe endpoint life cycle impact assessment method was selected in accordance with the indications of the EC/DEVCO – VCA4D Methodological brief. This document breaks down the framing question 4, "*Is the VC environmentally sustainable?*" into three core questions, focused on the potential impact of the VC in terms of (1) resources depletion; (2) ecosystem quality, and (3) human health, which correspond to the areas of protection included in the ReCiPe 2016, method (Huijbregts et al., 2017 and 2016)[41][42]. The Hierarchist version, with normalization set at World (2010), H/A was used. The indicators included in each damage category and their relationship with the three areas of protection are shown in Table 6.3. The endpoint method is based on the aggregation and normalization of the 18 midpoint categories in the above mentioned three areas of protection. This aggregation may simplify the interpretation of results and support decision-making, but at the same time, it has the drawback of increasing the uncertainties due to the models used to convert midpoint impacts in endpoint damage categories. In this section, to further support the interpretation of the results, also midpoint impacts were evaluated.

[41] *Huijbregts, M.A.J., Steinmann, Z.J.N., Elshout, P.M.F., Stam, G., Verones, F., Vieira, M., Zijp, M., Hollander, A., van Zelm, R., 2017. ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. Int. J. Life Cycle Assess. 22, 138–147. doi:10.1007/s11367-016-1246-y*

[42] *Huijbregts, M.A.J., Steinmann, Z.J.N., Elshout, P.M.F., Stam, G., Verones, F., Vieira, M.D.M., Hollander, A., Zijp, M., van Zelm, R., 2016. ReCiPe 2016: A harmonized life cycle impact assessment method at midpoint and enpoint level - Report I: Characterization, National Institute for Public Health and the Environment. Bilthoven, The Netherlands.*

Table 6-3: Summary of endpoint impact categories included in each damage category of the ReCiPe 2016 method used in this study.

Impact Category	Areas of protection			Description
	Human Health	Ecosystems	Resource scarcity	
Climate change	X	X		Greenhouse gas emissions causing disturbances on the global climate system
Stratospheric ozone depletion	X			Emissions of compounds such as chlorofluorocarbons or halons, which are responsible for the ozone hole phenomenon
Ionising radiation	X			Release of radioactive substances into the environment
Particulate matter formation	X			Emissions of particulate matter or particulate precursors, which contribute to respiratory disorders
Photochemical ozone formation	X	X		Emissions of ozone precursor pollutants such as nitrogen oxides or volatile organic compounds, causing human health problems (irritation, asthma) or damage to plants
Terrestrial acidification		X		Emissions of acidifying pollutants, causing phenomena such as acid rain, and damage to terrestrial ecosystems
Freshwater eutrophication		X		Emissions of nutrients into the natural environment, causing disequilibria in freshwater ecosystems (proliferation of plant or animal species at the expense of other species)
Toxicity and ecotoxicity	X	X		Emissions of pollutants toxic to human health and ecosystems
Water consumption	X	X		Effects for human population and ecosystems of freshwater consumption
Land use		X		Biodiversity changes due to land transformations and occupations
Mineral resource scarcity			X	Depletion of mineral ores
Fossil resource scarcity			X	Cumulated primary energy demand from fossil and nuclear sources

6.4.2 Environmental impacts of sorghum cultivation

Environmental impacts of the cultivation stage, estimated for the four groups of farm types (SHF1, SHF2, LMF and CF) are presented. Results also are compared with those of:

1) a virtual mix at farm gate of grains produced by SHF1 and SHF2 supplying to both sub-chain 1 and sub-chain 2 according to the shares shown in Table 3.1;
2) a mix of grains produced by SHF2, LMF and CF, according to the shares reported in Table 3.1;
3) the Best Scenario of Sorghum Farming-BSSF where sub-chain 2 is supplied exclusively by SHF2 with improved yields, and sub-chain 3 is supplied by SHF2, improved SHF2, LMF and CF.
4) The model for barley cultivation selected in this study for the simulation of sub-chain 3 (Barley, conventional, malting quality, national average, at farm gate/FR S, Agribalyse database, with a farm gate yield of 6.6 t/ha).

Table 6.4 shows the midpoint impact categories per kg of grain produced, of all groups farm types, of the *BSSF* and of the model for barley cultivation selected for the study. A selection of midpoint impact categories is represented in Figure 6.8, where original units were substituted by an index number (100) to make comparisons more immediate. It can be observed that in almost all categories, impacts are related to input levels and yields, the higher the level of external inputs, the higher the impacts as long as yields are relatively low. In the case of CF a more efficient use of external inputs (larger yields per unit of external inputs compared to the other systems) causes a reduction in all impact categories.

It is important to highlight that, any improvement in yields leads to a reduction in land use, even in cases of relatively inefficient use of external inputs causing high impacts in other categories (SHF1, SHF2, LMF). This is also the case of eutrophication. Under the conditions simulated for northern Ghana, with high soil loss due to erosion, the eutrophication potential is high. Therefore, the higher the yield, the smaller the impact per kg of grain produced.

Land use and eutrophication are important in terms of overall impacts of the cultivation stage, since both affect greatly the Endpoint ecosystem quality category. A better balance among all midpoint indicators would be obtained with the BSSF.

Table 6-4: Cultivation stage: Midpoint impact categories per kg of grain produced, of all groups farm types, of the BSSF and of the model for barley cultivation selected for the study.

Impact category	Unit	Sorghum at farm, SHF1	Sorghum at farm, SHF2	Sorghum at farm, LMF	Sorghum, at farm CF	Sorghum, at farm, BSSF	Barley, conventional, malting quality, national average, at farm gate/FR S
Global warming	kg CO2 eq	0.1496	0.2815	0.4408	0.3570	0.3350	0.4139
Stratospheric ozone depletion	kg CFC11 eq	3.36E-06	6.65E-06	1.07E-05	8.13E-06	8.06E-06	9.42E-06
Ionizing radiation	kBq Co-60 eq	4.65E-04	1.74E-03	3.35E-03	2.63E-03	2.32E-03	1.10E-02
Ozone formation, Human health	kg NOx eq	4.33E-04	4.12E-04	3.35E-04	4.52E-04	3.64E-04	1.44E-03
Fine particulate matter formation	kg PM2.5 eq	8.28E-05	2.84E-04	5.35E-04	4.26E-04	3.74E-04	9.52E-04
Ozone formation, Terrestrial	kg NOx eq	4.39E-04	4.18E-04	3.42E-04	4.60E-04	3.71E-04	1.46E-03
Terrestrial acidification	kg SO2 eq	2.06E-04	1.63E-03	3.45E-03	2.58E-03	2.30E-03	5.13E-03
Freshwater eutrophication	kg P eq	1.73E-02	1.32E-02	6.10E-03	4.38E-03	0.96E-02	1.24E-04
Marine eutrophication	kg N eq	8.91E-08	1.13E-06	2.48E-06	1.83E-06	1.63E-06	1.26E-03
Terrestrial ecotoxicity	kg 1,4-DCB	7.70E-03	1.05E-01	2.31E-01	1.70E-01	1.52E-01	1.07
Freshwater ecotoxicity	kg 1,4-DCB	5.70E-06	9.44E-04	2.16E-03	1.56E-03	1.40E-03	7.33E-03
Marine ecotoxicity	kg 1,4-DCB	5.05E-05	1.37E-03	3.07E-03	2.24E-03	2.00E-03	1.05E-02
Human carcinogenic toxicity	kg 1,4-DCB	3.79E-05	9.05E-04	2.03E-03	1.47E-03	1.32E-03	3.70E-03
Human non-carcinogenic toxicity	kg 1,4-DCB	4.34E-04	2.93E-02	6.66E-02	4.81E-02	4.31E-02	0.00E+00
Land use	m2a crop eq	16.1290	12.1957	5.6037	4.0346	8.89	1.4773
Mineral resource scarcity	kg Cu eq	3.41E-05	9.40E-04	2.11E-03	1.54E-03	1.37E-03	1.75E-03
Fossil resource scarcity	kg oil eq	1.79E-02	3.69E-02	5.96E-02	5.16E-02	4.46E-02	5.36E-02
Water consumption	m3	7.39E-04	1.05E-03	1.44E-03	1.25E-03	1.19E-03	8.23E-03

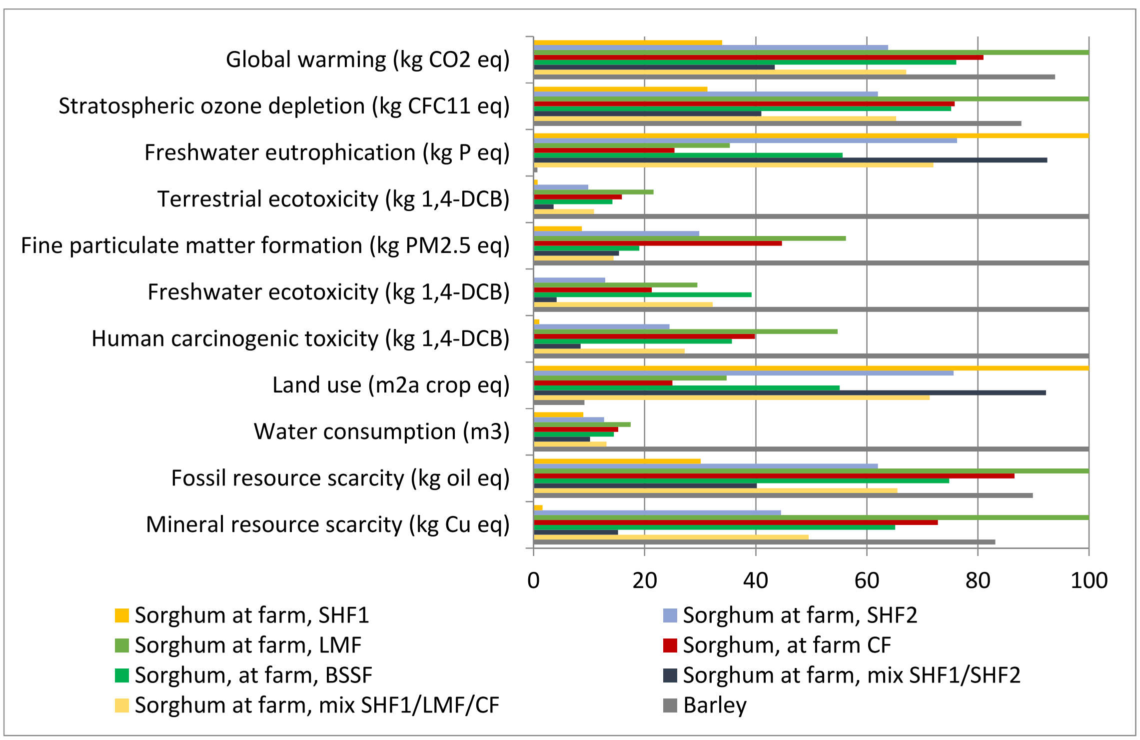

Figure 6-8: Cultivation stage: Selection of midpoint impact categories. Original units were substituted by an index number (100) to make comparisons more immediate.
Source: Authors

Endpoint results are shown for 1 kg of sorghum grains and barley grains for each impact category in Figure 6.9. Original units were substituted by an index number (100) to make comparisons more immediate. Figures 6.10 and 6.11 show results as endpoint values for each impact category, and in terms of damage for the three domains.

Considering the three damage categories, cultivation of sorghum affected mostly the ecosystem quality, mainly due to land use and to freshwater eutrophication due to soil erosion and to N and P fertilizers, applied by all categories of farmers, except SHF1. Contribution of freshwater eutrophication due to soil erosion resulted high under the conditions simulated on the basis of literature data for areas under sorghum cultivation in northern Ghana. Barley cultivation does not have such high impacts on ecosystem quality, in particular due to a more efficient land use, determined by the high grain yield of barley (6.6 t/ha).

Human health is affected to a lesser extent by sorghum cultivation, in particular in low-input systems of sorghum cultivation. This damage category is influenced by global warming (N_2O emissions from soil, production of NPK fertilisers and combustion emissions for mechanical operations) and by fine particulate matter formation, derived from NH_3 emissions from nitrogen fertilization and from mechanical operations.

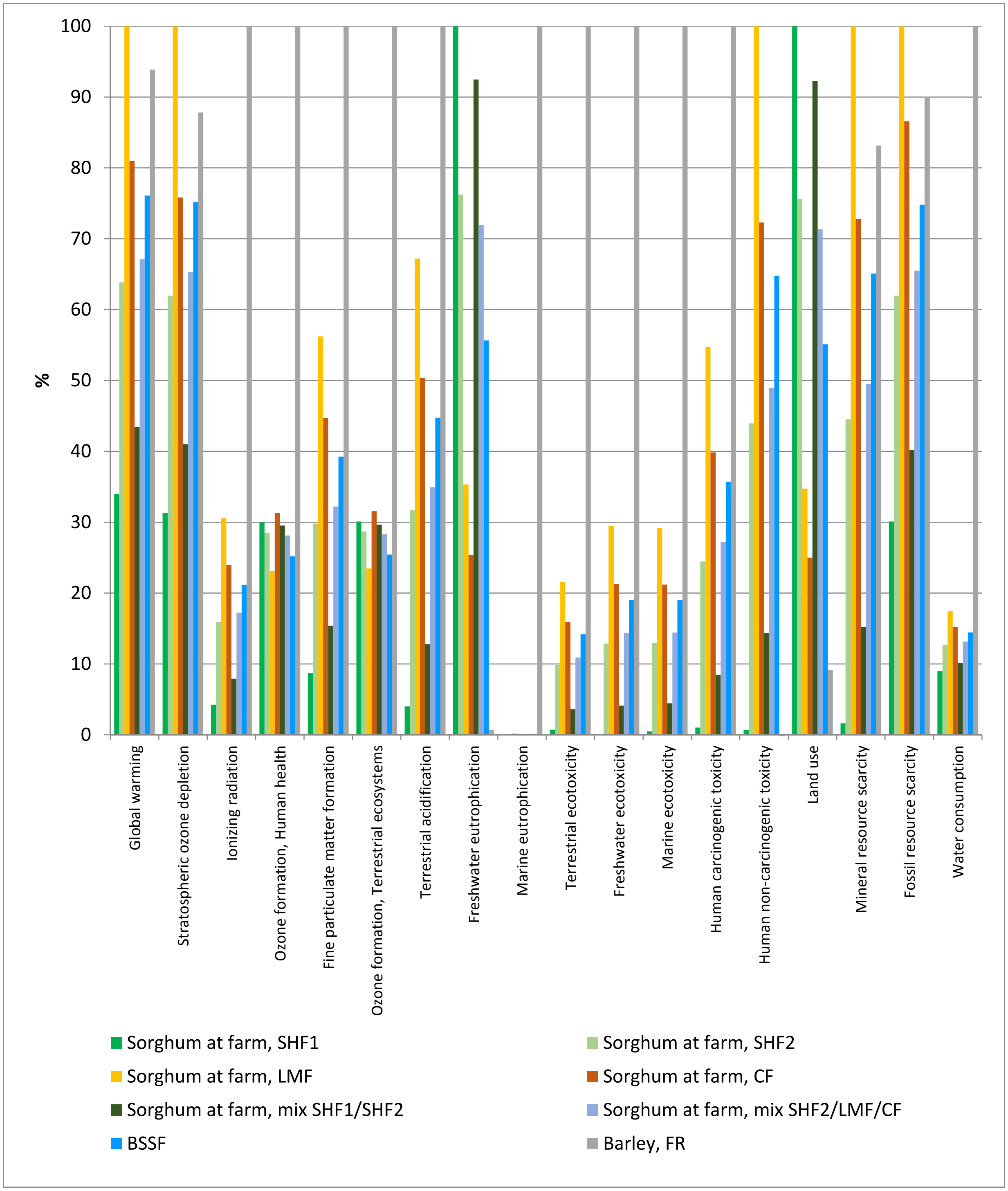

Figure 6-9: Cultivation stage. Relative endpoint values for all the impact categories, SHF1, SHF2, LMF and CF farms, grain mixes (SHF1/SHF2, CF/LMF), BSSF, and barley cultivation (1 kg of grains).

Source: Authors

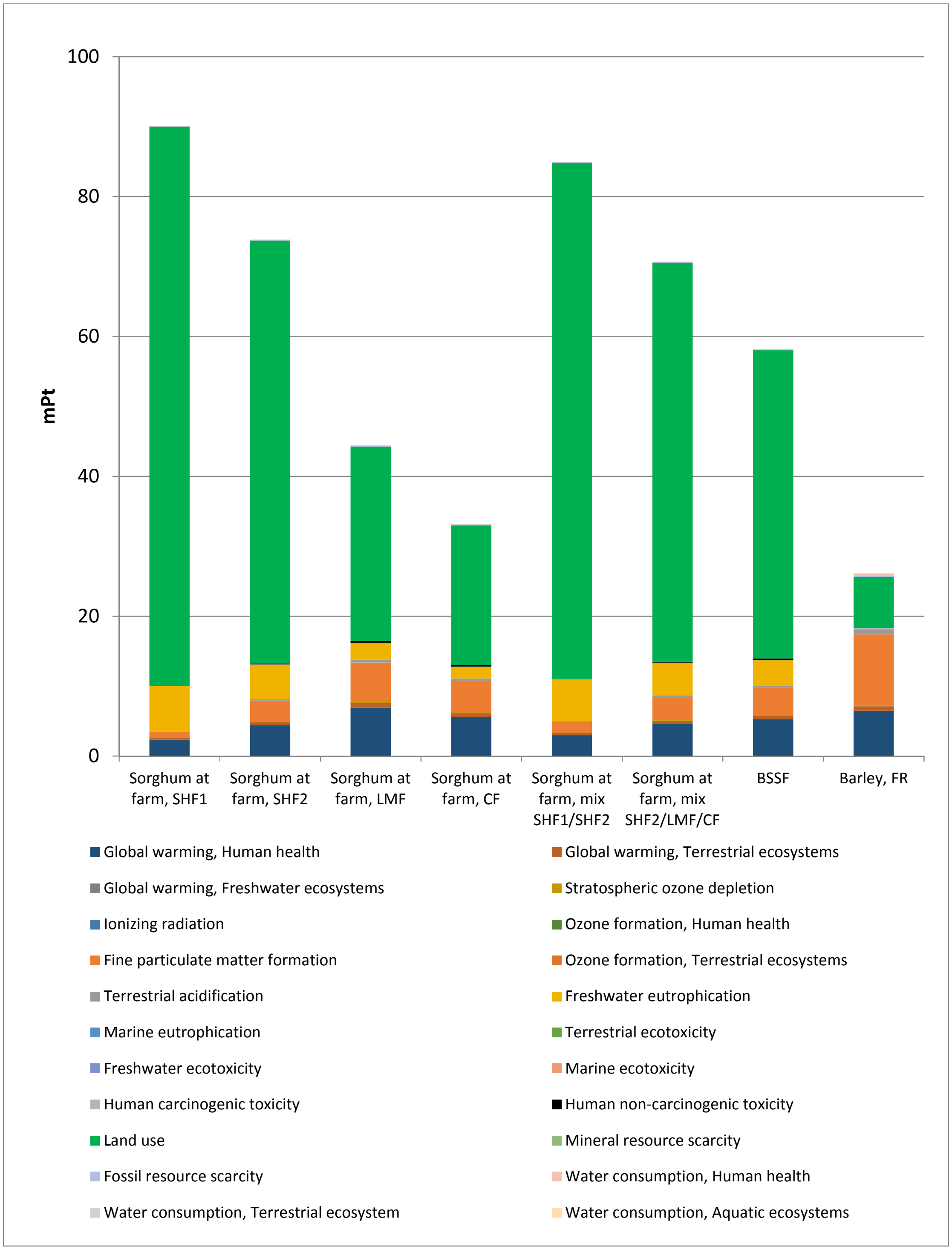

Figure 6-10: Cultivation stage. Endpoint values for each impact category, SHF1, SHF2, LMF, CF farms, grain mixes (SHF1/SHF2 and SHF2/LMF/CF), BSSF and for barley cultivation (1 kg of grains)
Source: Authors

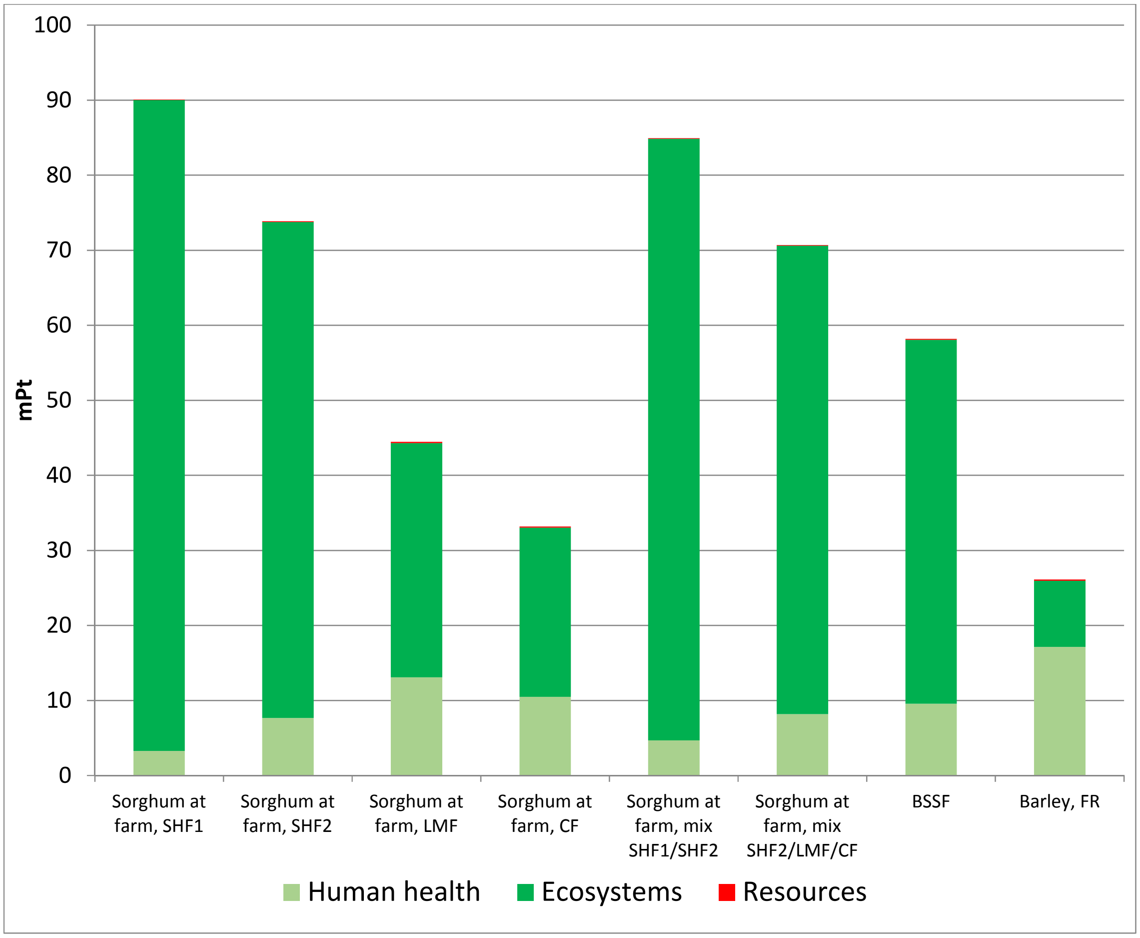

Figure 6-11: Cultivation stage. Endpoint impacts for each damage category SHF1, SHF2, LMF and CF farms, grain mixes (SHF1/SHF2 and SHF2/LMF/CF), BSSF and barley cultivation (FU: 1 kg of grains).
Source: Authors

6.4.3 Life cycle environmental impacts of three sub-chains

Results of the business-as-usual scenarios for the three sub-chains are shown in this section, along with a summary of the results of the comparisons of the scenarios in Table 6.2

A summary, comprising all sub-chains and scenarios is presented. Discussion of this summary should not be interpreted as a formal comparison of the sub-chains and the scenarios, since as explained previously comparisons among different types of products, *pito* and beer, are not compliant with the ISO 14040 – ISO 14044 framework.

Environmental impacts of the pito sub-chain: business-as-usual scenario
Relative contribution of midpoint impact categories for sub-chain 1, supplied by SH1 and SHF2 is reported in Figure 6.12. It can be seen, that cultivation largely affects land use and freshwater eutrophication, where contributions of the cultivation stage are close to 100%. Firewood extraction and combustion is the main contributor to global warming potential and to the impact categories affecting mainly human health and ecosystems, as it can be seen from the endpoint indicators results. These are reported for each life cycle stage, for impact categories and damage categories, respectively (Figures 6.13 and 6.14). These figures show the large impact of firewood for brewing, which under the single score perspective is the main hotspot, followed by the cultivation stage.

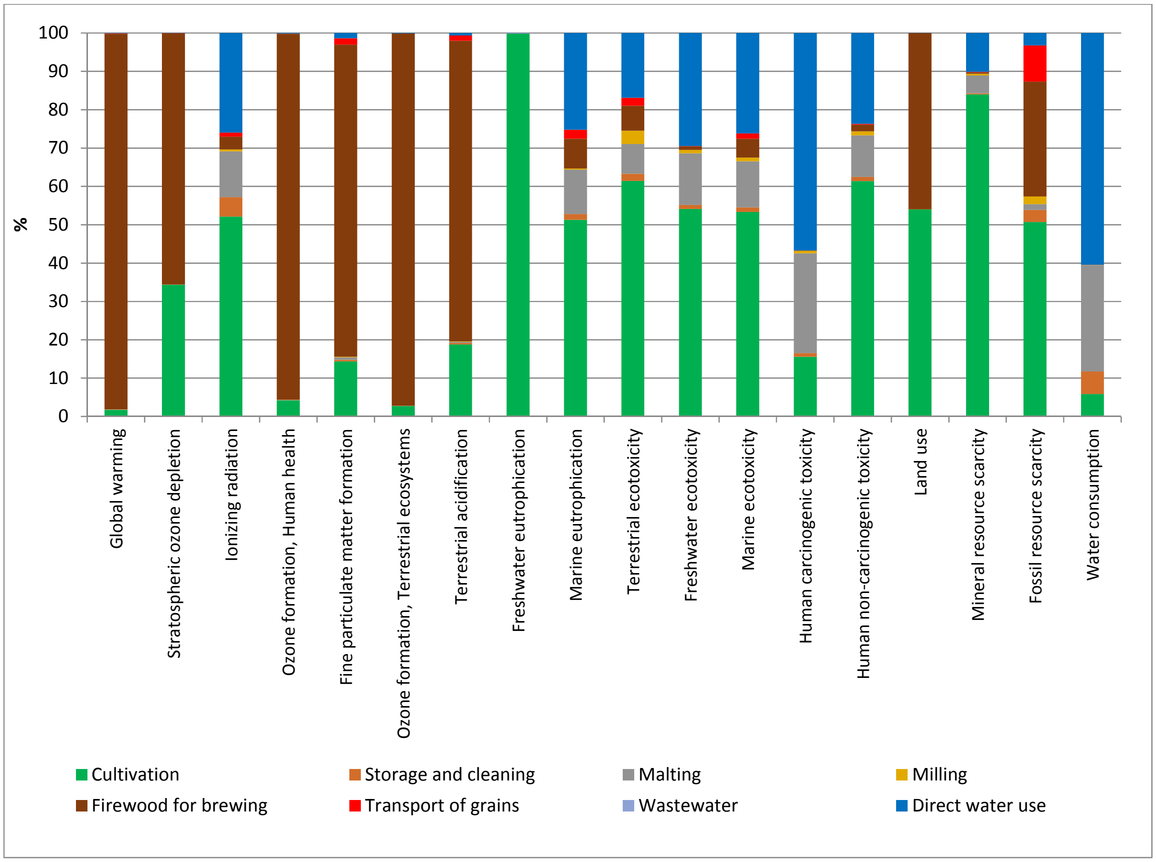

Figure 6-12: Relative values of each midpoint impact category of 1 L of pito (open-fire brewing)
Source: Authors

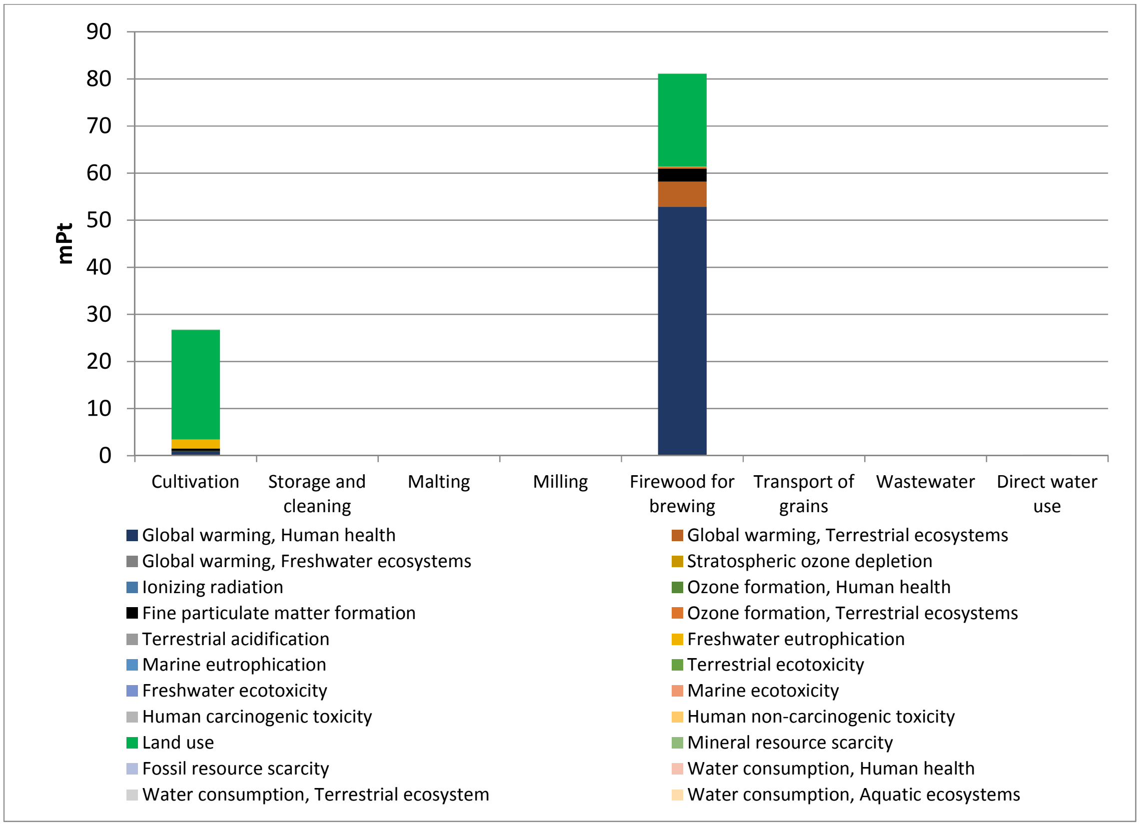

Figure 6-13: Endpoint impact categories for all life cycle stages of the production of 1 L of pito (sub-chain 1 supplied by SHF1/SHF2, open-fire brewing)
Source: Authors

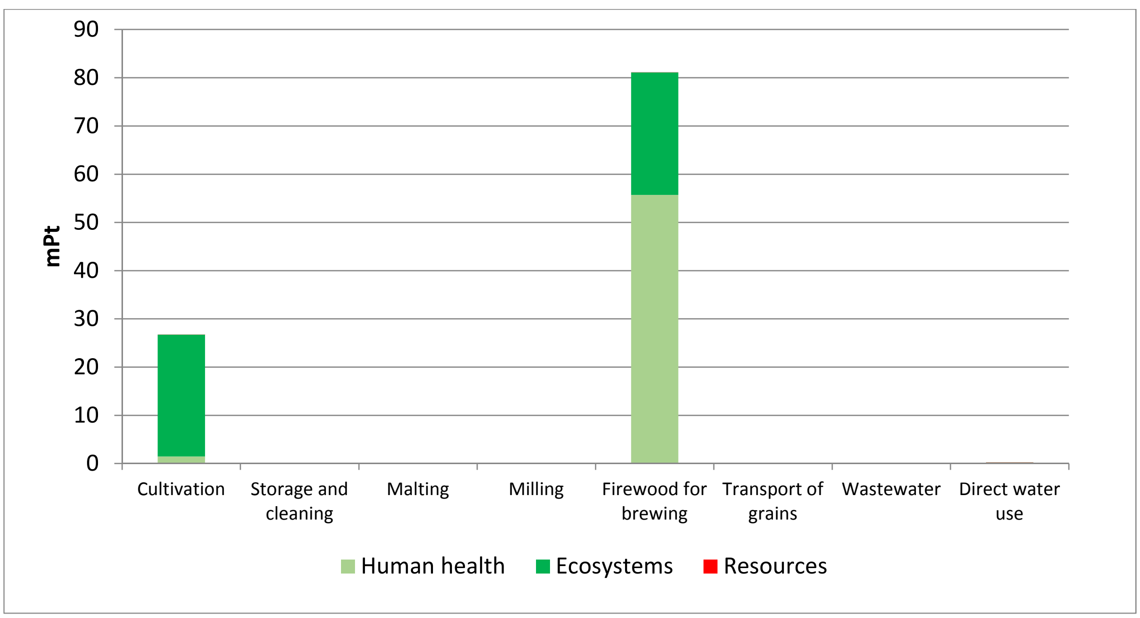

Figure 6-14: Endpoint damage categories for all life cycle stages of the production 1 L of pito (sub-chain 1 supplied by SHF1/SHF2, open-fire brewing).
Source: Authors

Summary of the impact assessment of sub-chain 1

The summary of the comparisons scenarios of sub-chain 1 (business-as-usual: open fire brewing and best case: reduction firewood use by 50%) are shown in Figure 6.15 for the three domains of damage.

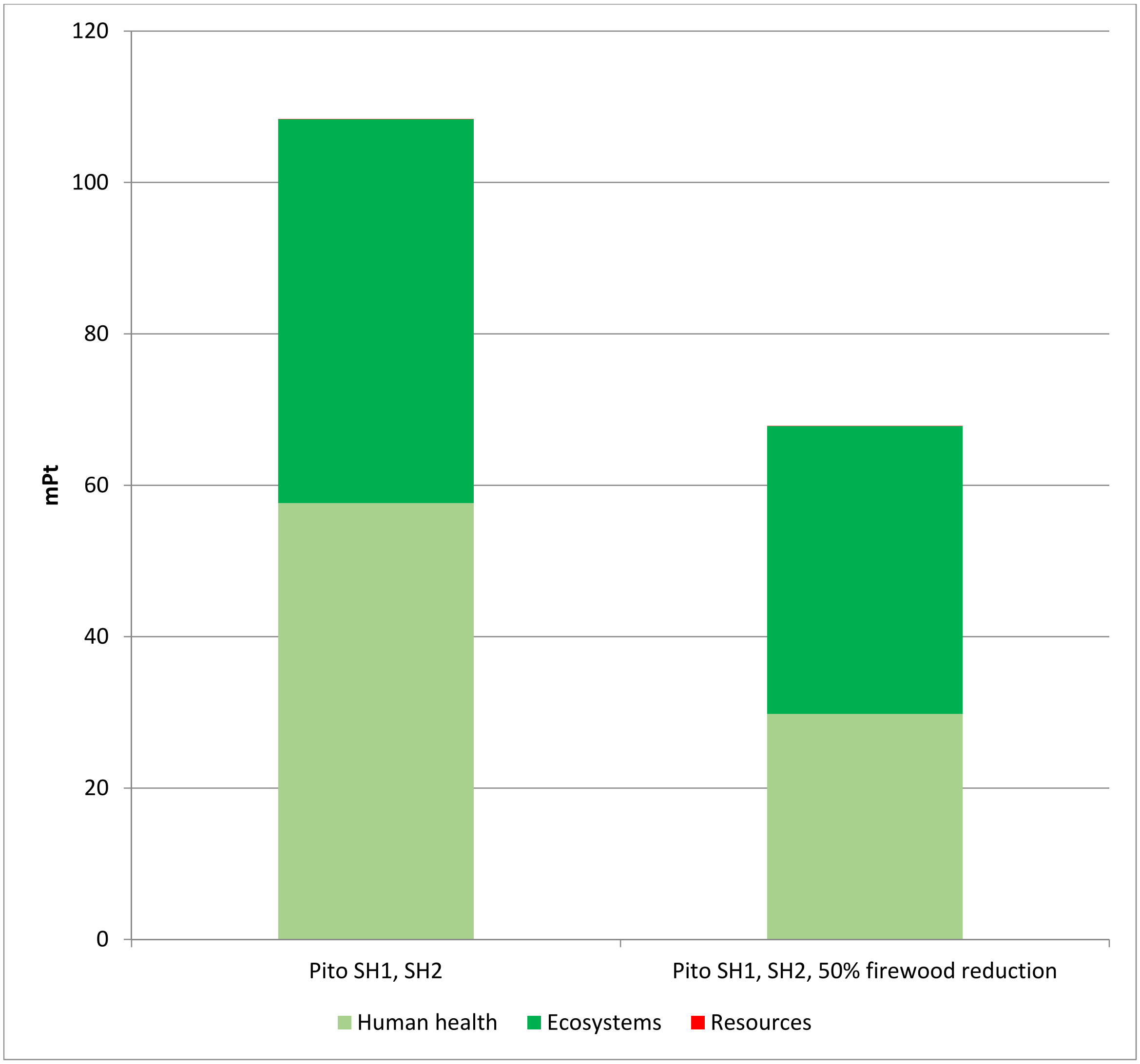

Figure 6-15: Endpoint values for each impact category, for (1) sub-chain 1, open-fire brewing and (2) sub-chain 1 (50% firewood reduction). FU: 1 L of pito.
Source: Authors

Environmental impacts of the microbrewery sub-chain: business-as-usual scenario

Relative contribution of midpoint impact categories for sub-chain 2, supplied by SHF1 and SHF2 is reported in Figure 6.16. It can be seen, that cultivation mainly affects land use and freshwater eutrophication, where contributions of the cultivation stage are close to 100%. Energy use for brewing (diesel and grid electricity) has the main contribution across most impact categories. Nevertheless, it can be seen that due to the relatively large impact of agricultural land use on ecosystems quality, as shown in Figures 6.17 and 6.18, the overall impacts of energy consumption for brewing are relatively low.

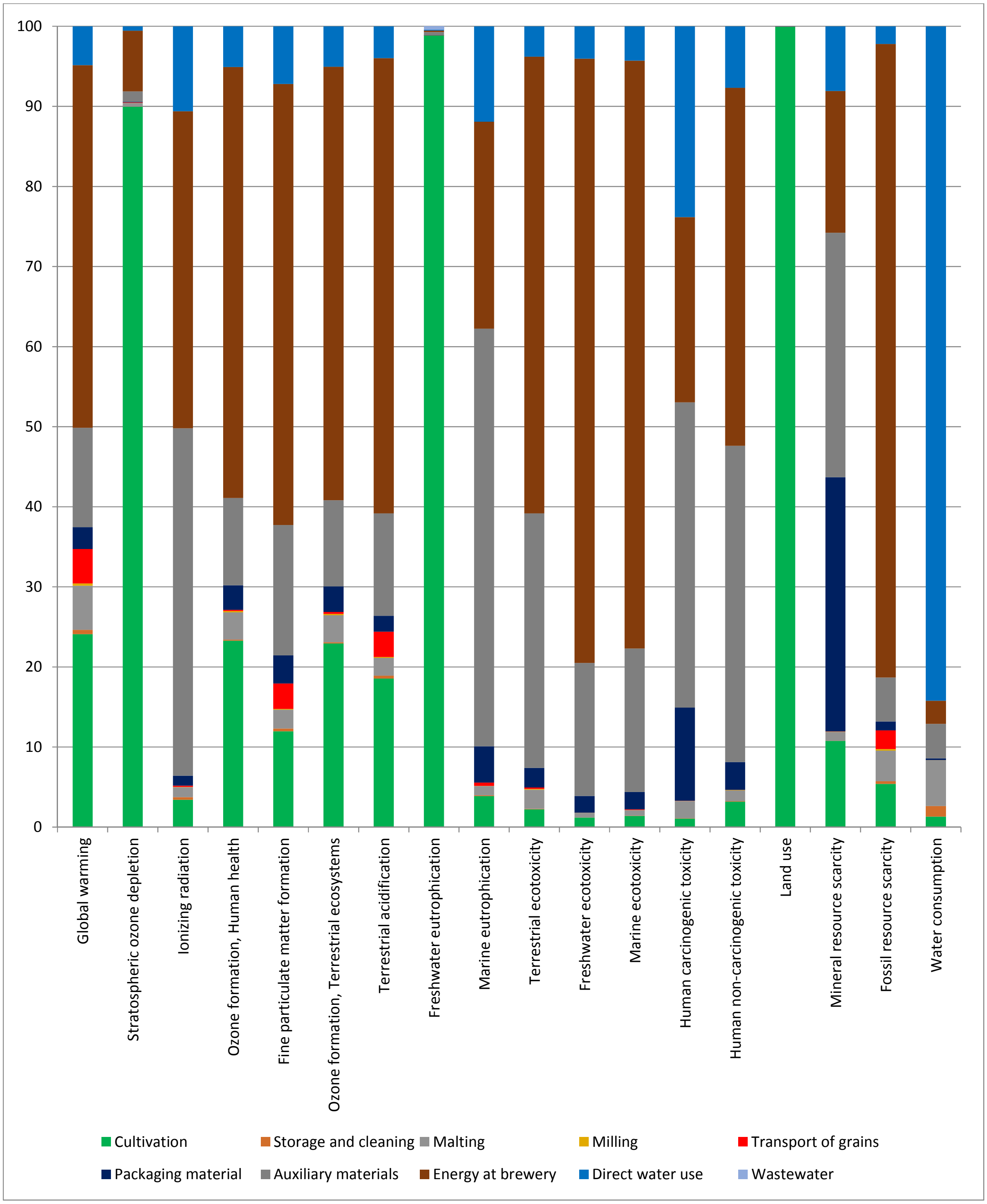

Figure 6-16: Relative value of each midpoint impact category of 1 L of beer (sub-chain 2 supplied by SHF1 and SHF2)
Source: Authors

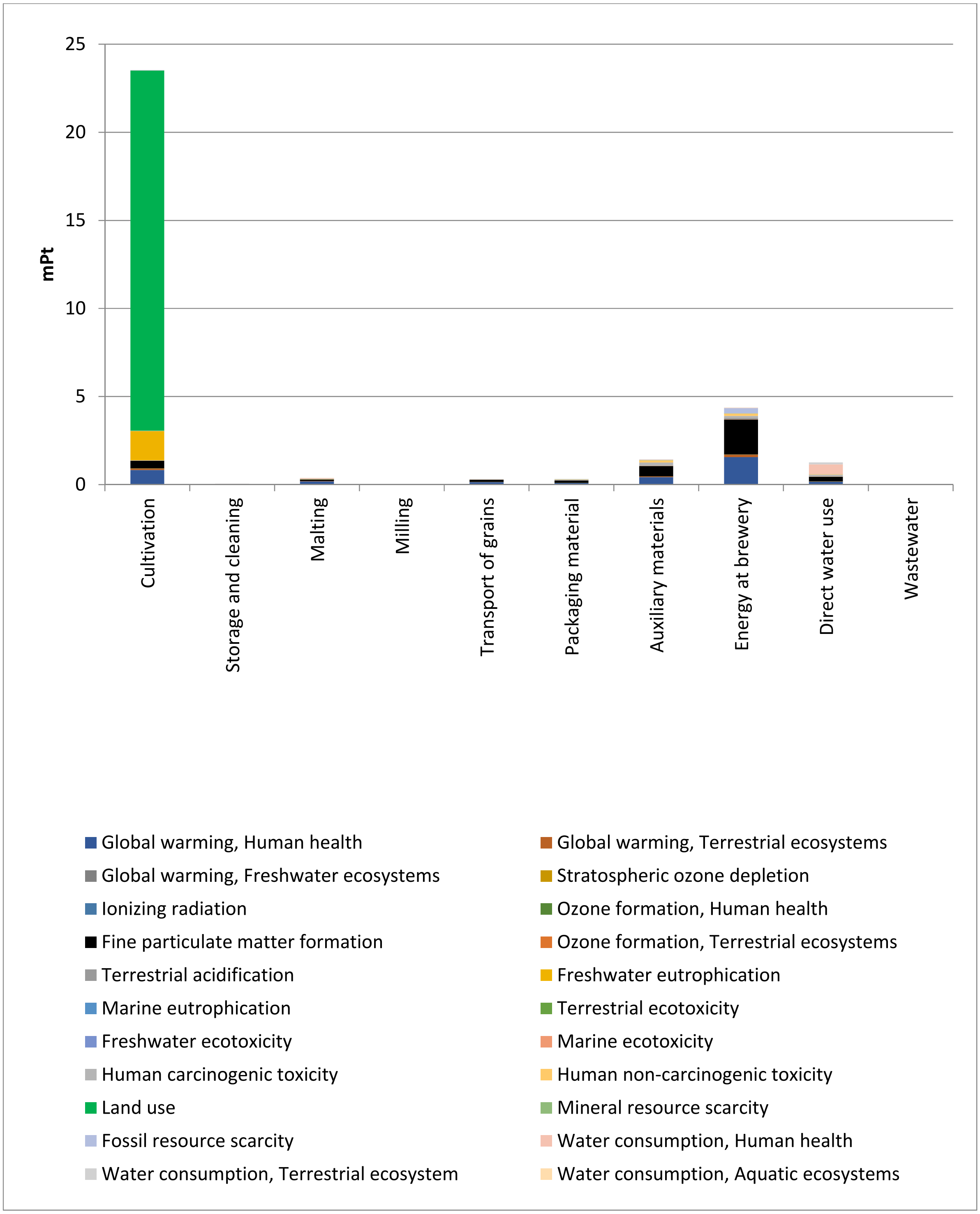

Figure 6-17: Endpoint impact categories per life cycle stage for the production of 1 L of beer (sub-chain 2 supplied by SHF1 and SHF2).

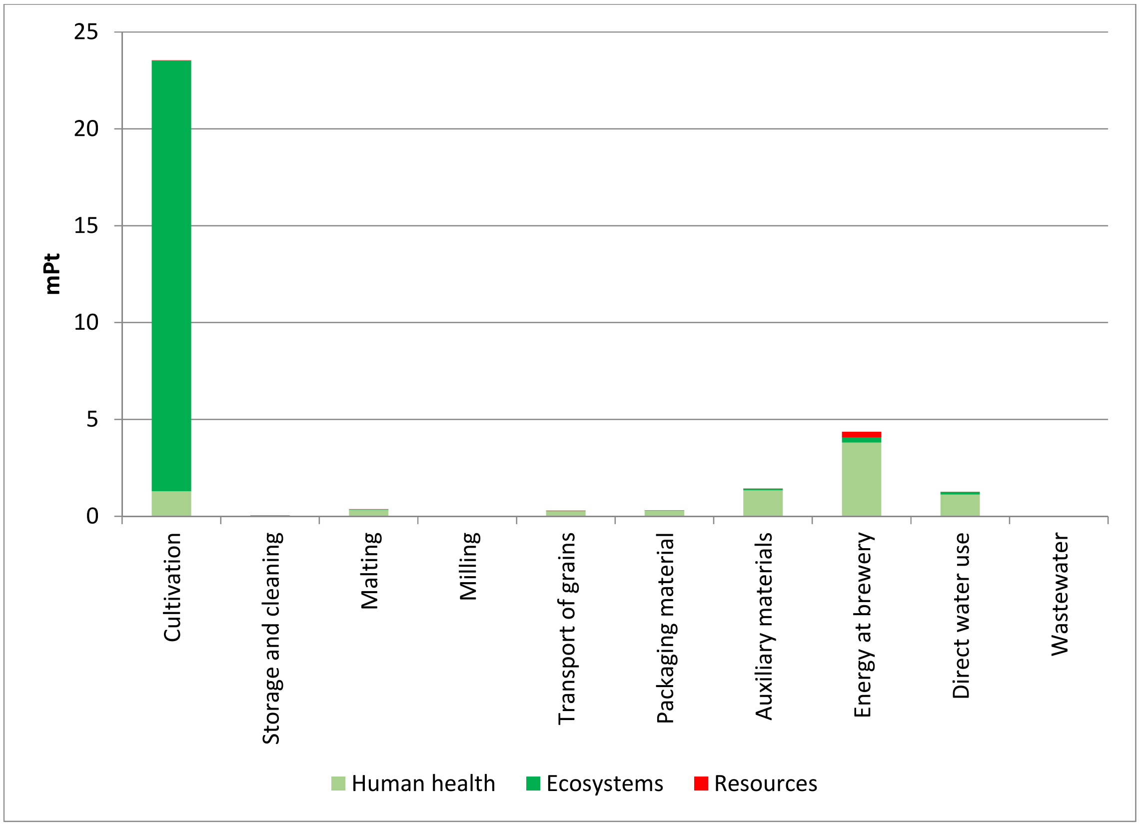

Figure 6-18: Endpoint damage categories per life cycle stage for the production of 1L of beer (sub-chain 2 supplied by SHF1 and SHF2)
Source: Authors

Summary of the impact assessment of sub-chain 2

The summary of the comparisons of the two scenarios of sub-chain 2 (BAU scenario: microbrewery, supplied by SHF1/SHF2 and best-case: microbrewery under BSSF –supplied by SHF2 using 100% inputs, with improved yields–) is shown in figure 6.19 in terms of endpoint results for the three domains of damage. Overall Endpoint results would improve under the best-case scenario, in which grain produced under BSSF is assumed. This is mainly due to the large impacts of the agricultural stage within this sub-chain, in particular from the Ecosystems perspective, which would be affected under the BSSF.

The alternative scenario for sub-chain 2 (BSSF scenario), would determine variations mainly in terms of ecosystem quality, while the human health domain is affected to a lesser extent.

Sourcing microbreweries with grains from BSSF would imply substitution of grains produced by SHF1+SHF2 (low input/low yield, with contribution of 64.7% and 35.2% respectively, see Tab. 3.1) with grains produced by a higher input cropping system (SHF2, 100% inputs –use of improved seeds, NPK: 250 kg/ha; SOA: 125 kg/ha, mechanical ploughing, 50% mechanical threshing–) with improved grain yield. Such substitution would determine higher impacts on human health at the cultivation stage. Indeed, human health is mainly influenced by two impact categories, in the cultivation stage 1) global warming due to N_2O emissions from soil, production of NPK fertilisers and combustion emissions for mechanical operations, and by 2) fine particulate matter formation, derived from NH_3 emissions from nitrogen fertilization and from mechanical operations. These two impact categories are therefore influenced by the level of intensification of cropping systems.

Although the impacts of the cultivation stage have a relatively modest contribution to the human health domain of the whole sub-chain (15% under BAU scenario, see Fig 6.27), the overall impact on human health of this sub-chain would slightly increase when substituting grain sourcing from the current combination of suppliers (SHF1+SHF2) with grain sourced under the BSSF scenario.

Since under the alternative scenario all other life cycle stages remain unchanged, the variation in terms of human health is attributed exclusively to changes in the cultivation stage.

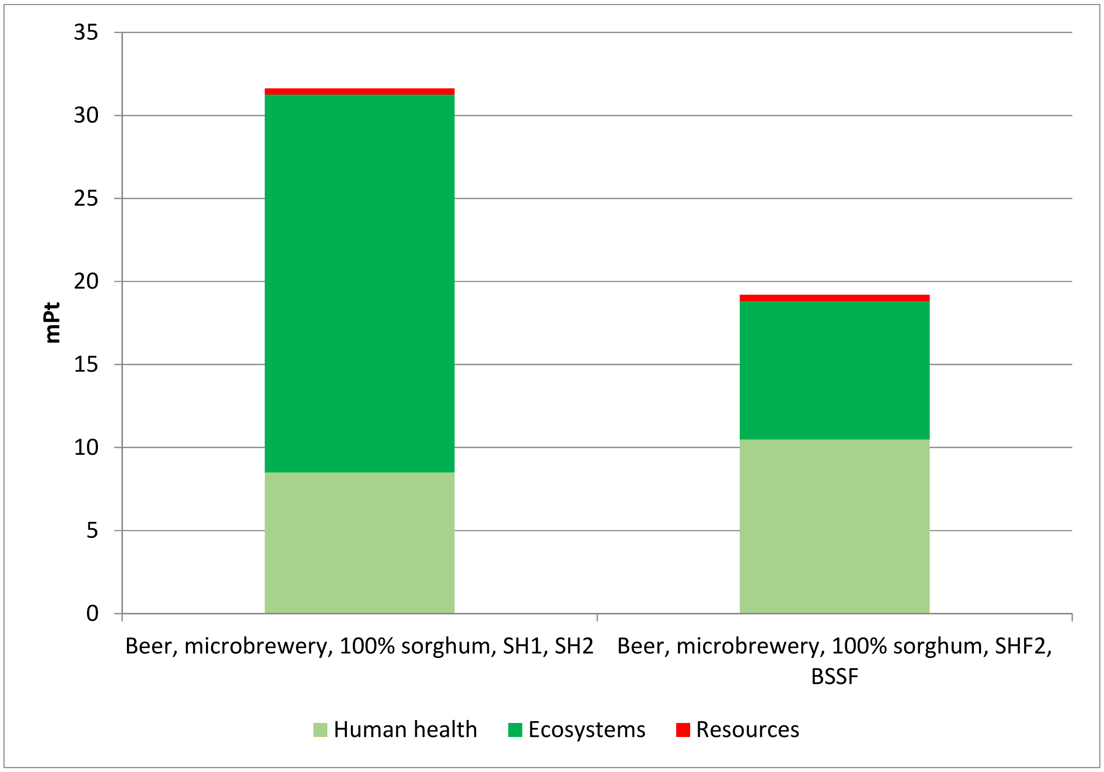

Figure 6-19: Endpoint values for each impact category, for (1) sub-chain 2 supplied by SHF1/SHF2, (2) sub-chain 2 under BSSF. FU: 1 L of beer.
Source: Authors

Environmental impacts of the industrial brewery sub-chain: business-as-usual scenario

Relative contribution of midpoint impact categories for sub-chain 3, supplied by SHF2, LMF and CF is reported in Figure 6.20. It can be seen that cultivation mainly affects land use and freshwater eutrophication. Production of packaging material (glass bottles) has the largest contribution across most impact categories. The production of glass containers affects mostly human health and ecosystems due to fine particulate matter formation and global warming, as it can be seen from the endpoint indicators results. As already discussed in section 6.3.3, it has been shown by several authors that glass bottle production is a major contributor to the life cycle impacts of industrial beer production chains. Results are reported for each life cycle stage in Figure 6.21 and 6.22, for impact categories and damage categories, respectively.

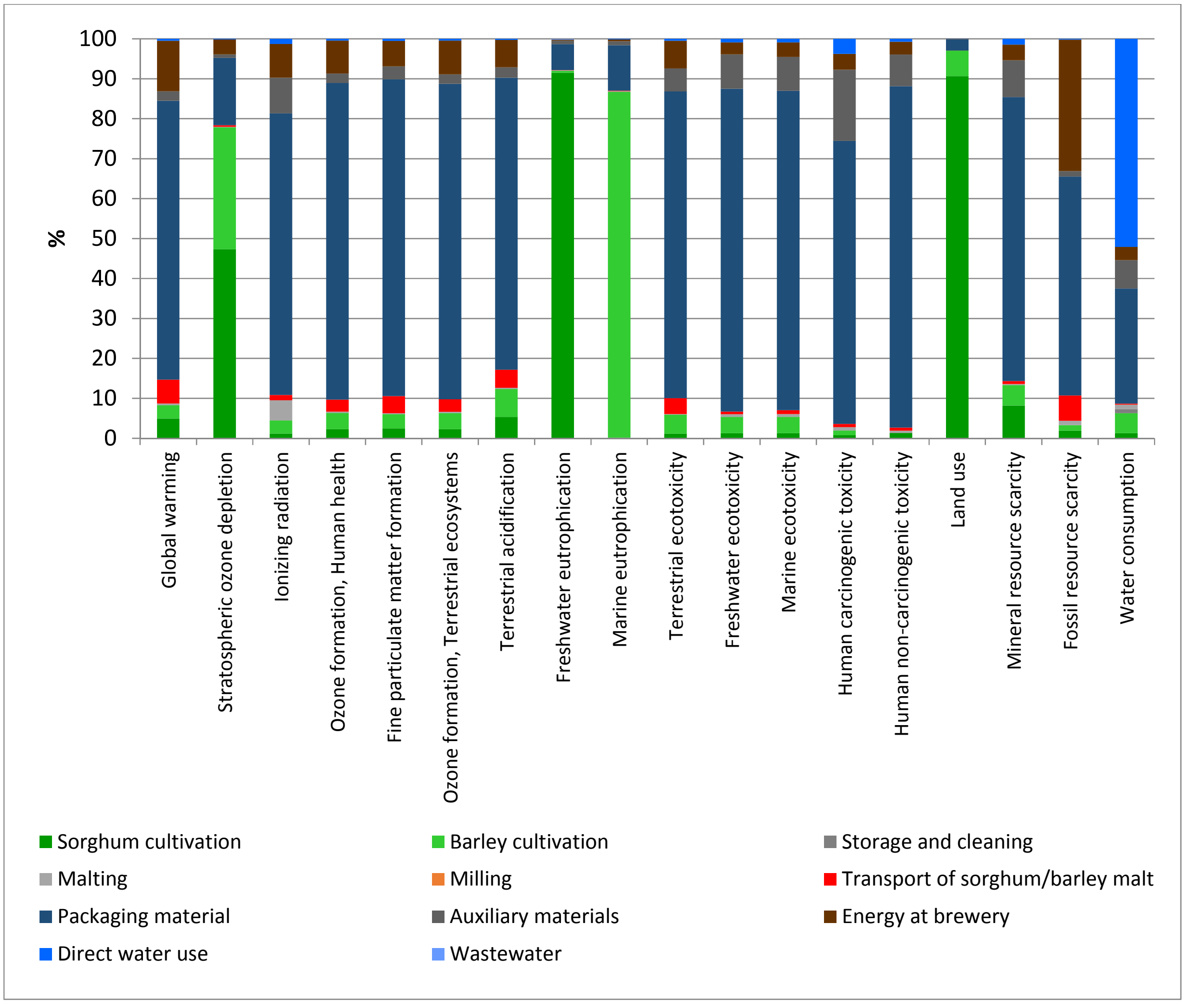

Figure 6-20: Relative value of each midpoint impact category for the production of 1 L of beer (sub-chain 3 supplied by SHF2, LMF and CF).
Source: Authors

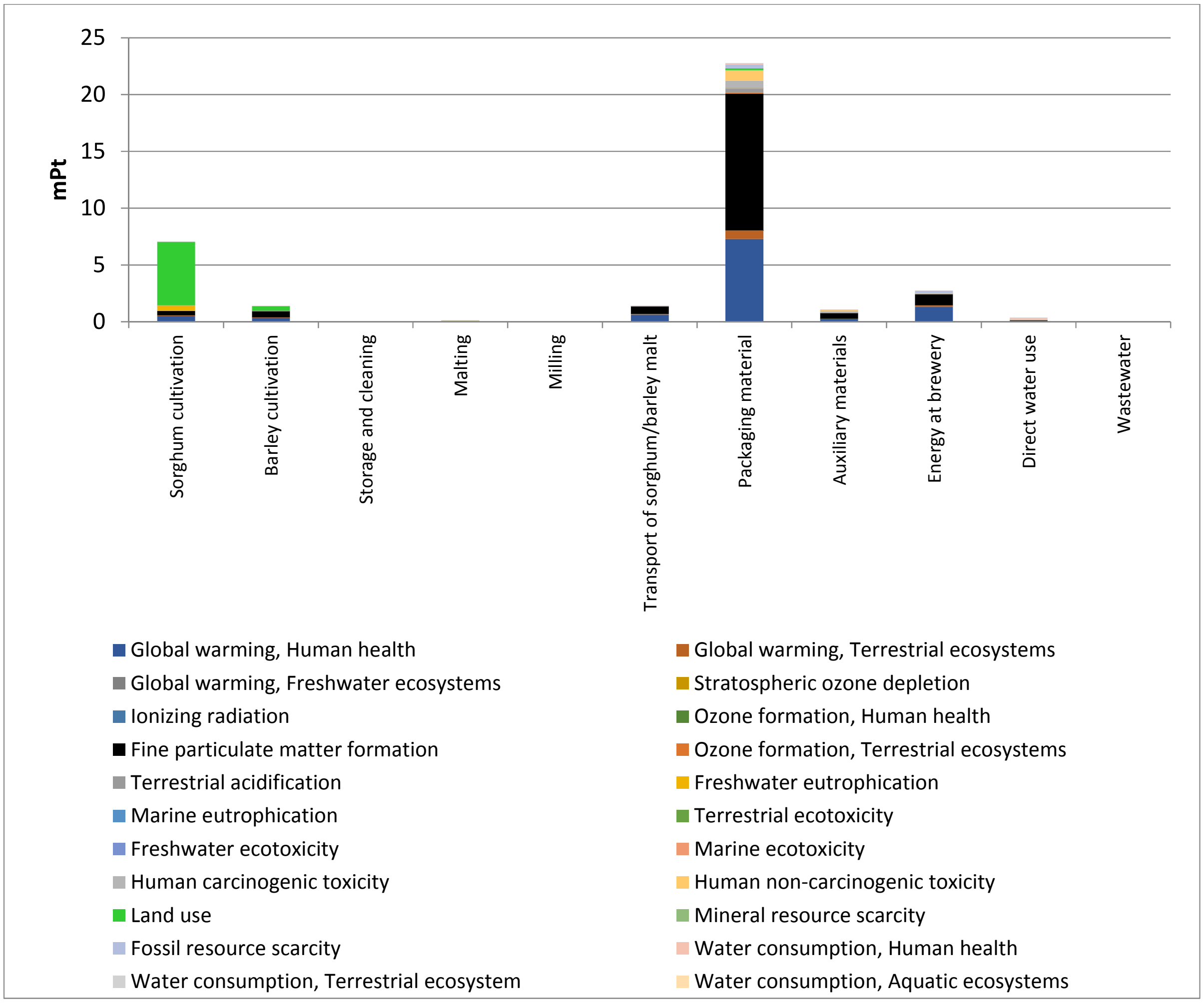

Figure 6-21: Endpoint impact categories per life cycle stage for the production of 1 L of beer (sub-chain 3 supplied by SHF2, LMF and CF)

Source: Authors

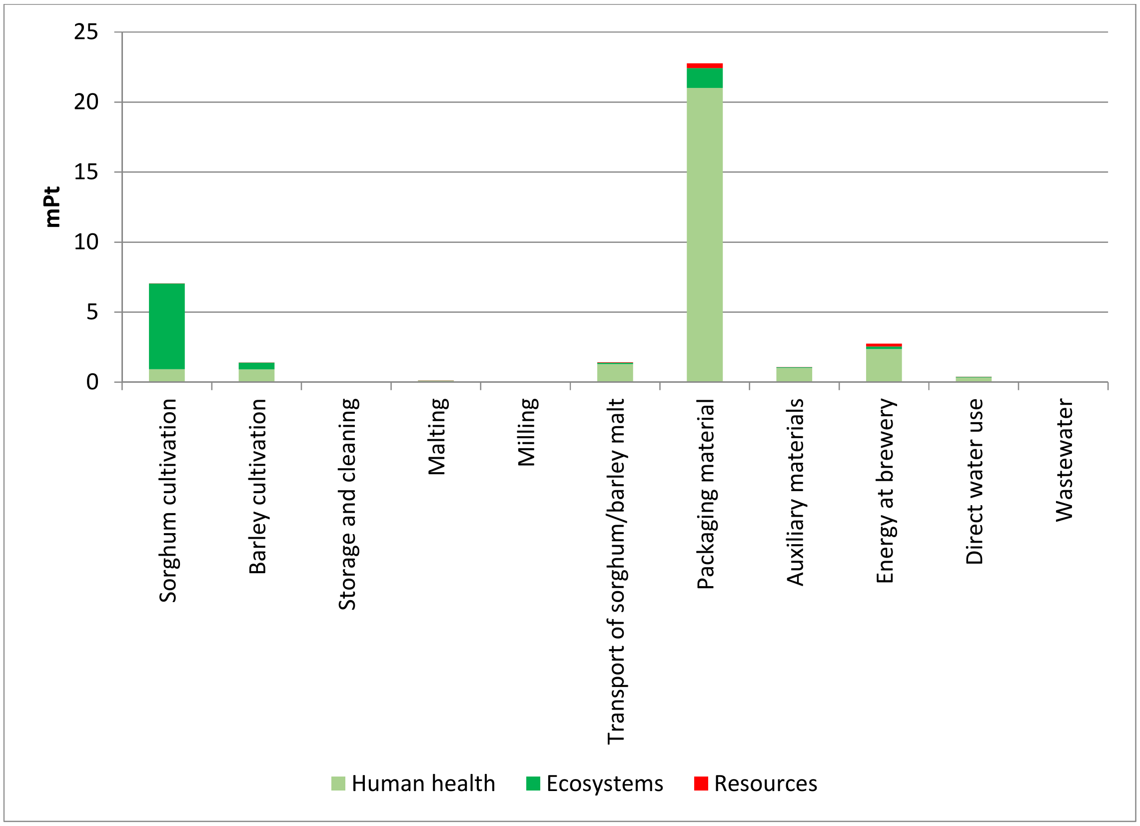

Figure 6-22: Endpoint damage categories per life cycle stage for the production of 1L of beer (sub-chain 3 supplied by SHF2, LMF and CF)
Source: Authors

Summary of the impact assessment of sub-chain 3

The summary of the comparisons of the three scenarios for sub-chain 3 (Table 6.5) are shown for the three domains of damage in figure 6.23. The best-case scenario, in which grain produced by *BSSF* is assumed, would have a slight positive impact, but the overall improvement would be modest. This is due to the large impacts of glass containers production which dominates the life cycle of the product. It is noteworthy though, that production of commercial beer (70% sorghum) under the *BSSF* would produce better overall endpoint results, which are comparable to those of the scenario of brewing with imported barley malt alone, which has low impacts in terms of land use (that reflects on the ecosystems category) due to the high grain yields of the selected crop production system.

Table 6-5: scenarios of sub-chain 3

	Type of scenario		
	Business-as-usual	Best-case	Benchmark
Sub-chain 3	Sub-chain 3, supplied by SHF2, LMF and CF	Sub-chain 3, under BSSF	Sub-chain 3, barley malt brewing alone

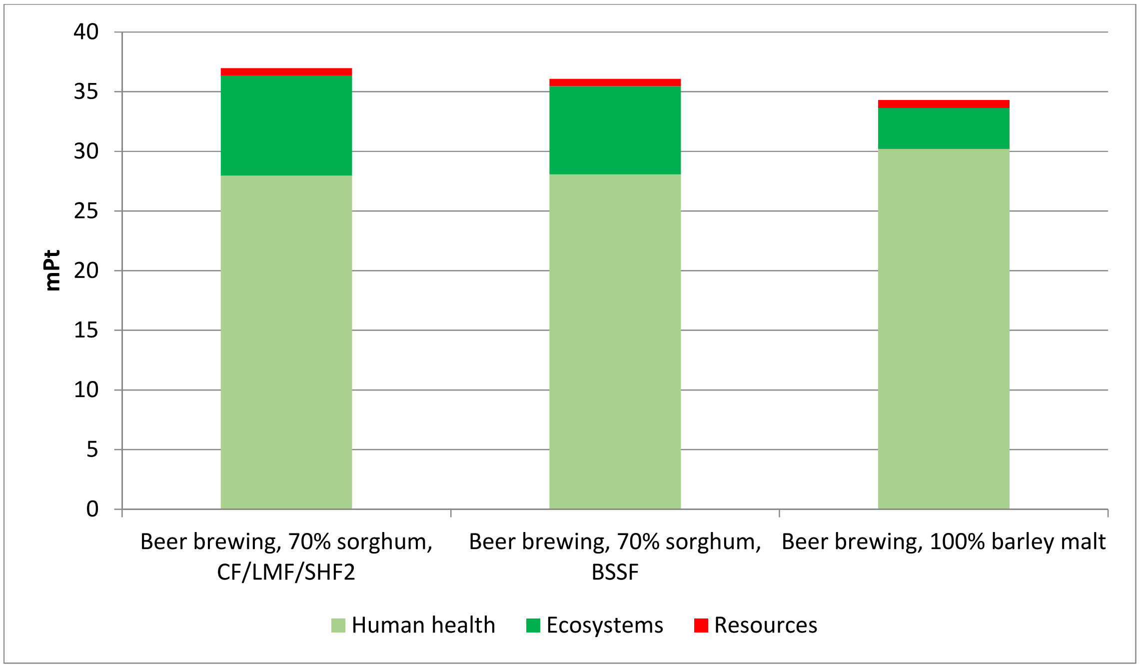

Figure 6-23: Endpoint values for each impact category, for (1) sub-chain 3, supplied by SH2, LMF and CF (2) sub-chain 3, under BSSF and (3) benchmark for sub-chain 3 barley malt beer. FU: 1 L of beer.
Source: Authors

6.5 Interpretation and discussion of results

Endpoint values for each impact category across the three sub-chains and all examined scenarios are shown in Figure 6.24. In sub-chain 1 the main impact categories are global warming and land use. The introduction of improvements in the value chain would greatly affect these two categories. In particular, these categories would be affected both by a provision of grains under the BSSF and by the introduction of the more efficient brewing technology (ovens), which could allow to reduce firewood consumption for brewing. In sub-chain 2, the main impact category is land use. Also in this case, the effects of improved agricultural practices leading to improved yields across all categories of farmers would have significant effects on land use.

In sub-chain 3 the main impact categories are fine particulate formation mostly due to glass packaging production. Within this chain, even though the overall environmental performance is not greatly affected by changes in the agricultural stage, it can be observed a slight improvement on land use (a modest decrease in this impact category) when introducing the scenario of grain provision under BSSF, alongside a slight reduction in the overall environmental impact of the sub-chain compared to the BAU and the benchmark scenario. This reflects in a very modest improvement in terms of overall endpoint impacts.

Differences observed between sub-chains 2 and 3 are mainly due to packaging materials. In fact, in accordance with previous studies (Cimini and Moresi, 2006, several EPD®: *Carlsberg®* 2016, *Tuborg®* 2016, *Angelo Poretti®* 2016, *Kronenbourg®*, 2016), the reusable keg packaging determines a much smaller environmental impact compared to the use of glass packaging.

Endpoint impacts for each damage category across the three sub-chains and all examined scenarios are shown in Figure 6.25. Overall, within sub-chain 1, potential improvements associated with the scenarios (firewood reduction) are more evident than in the cases of sub-chains 2 and 3. Nevertheless, in the latter cases, as discussed previously, some positive effects can also be expected. Midpoint impacts are shown for all scenarios (business-as-usual, best-case and benchmark) in Table 6.6. It must be reminded that these figures are not intended for comparison, as explained previously, but to provide a straight-forward overview. The overview presented in figure 6.25 shows that sub-chain 2 (microbrewery) has lower overall environmental impacts. In the BAU scenario this is due to the reduced impacts of packaging (reusable kegs). Impacts of the other two sub-chains (pito and commercial beer) are higher than those of sub-chain 2. In the case of pito, this is due to the use of firewood, lower rates of conversion grains/pito (compared to those of beer) and low yields of SHF1 and SHF2 supplying sub-chain 1. In the case of commercial beer, this is due mainly to the impacts of glass packaging, as discussed previously.

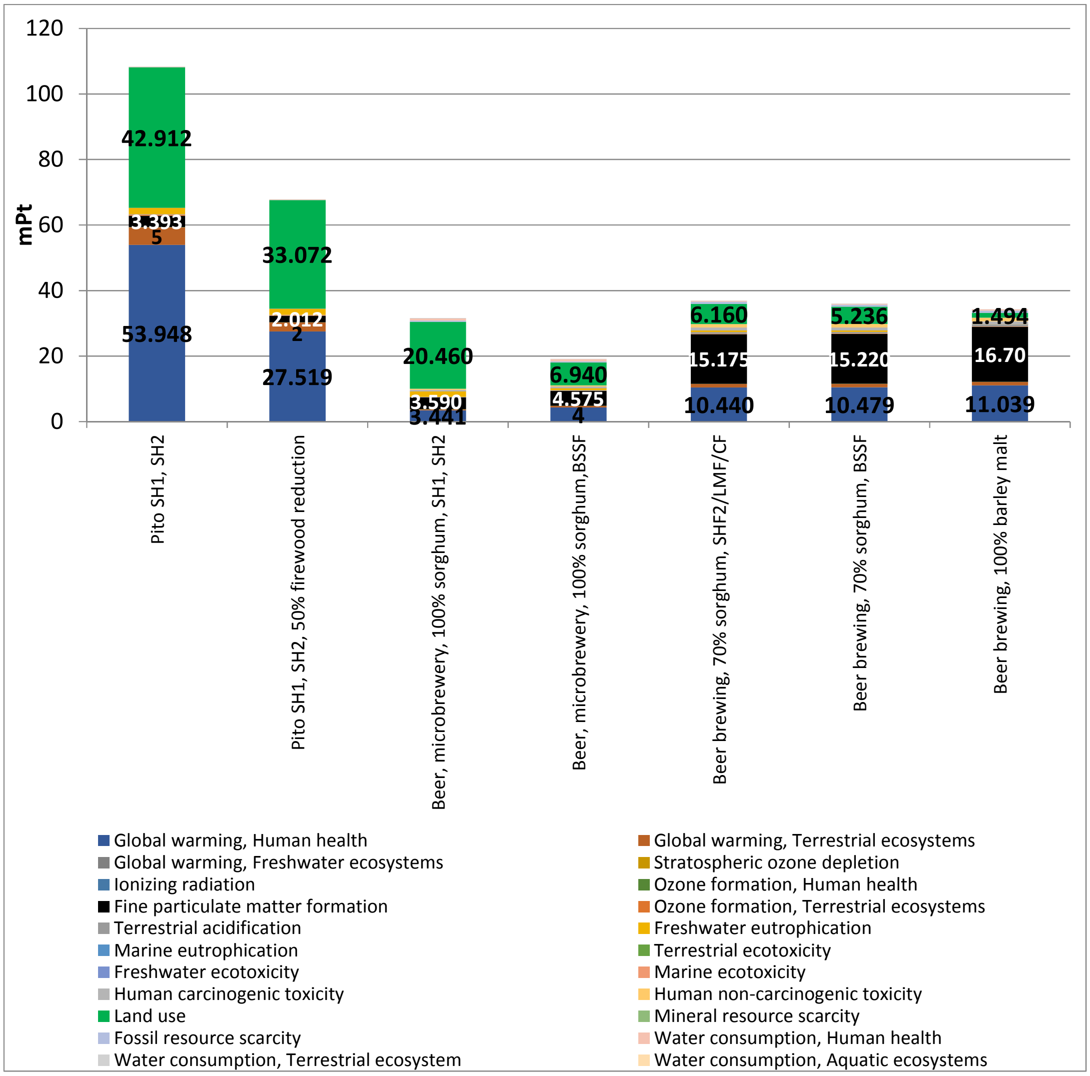

Figure 6-24: Overview of endpoint values for each impact category across the three sub-chains.
From left to right: sub-chain 1-SHF1/SHF2, sub-chain 2-SHF1/SHF2 (50% firewood), sub-chain2-SHF1/SHF2, sub-chain 2-BSSF, sub-chain 3-SHF2/LMF/CF, sub-chain 3-BSSF, sub-chain3-barley malt.
Source: Authors

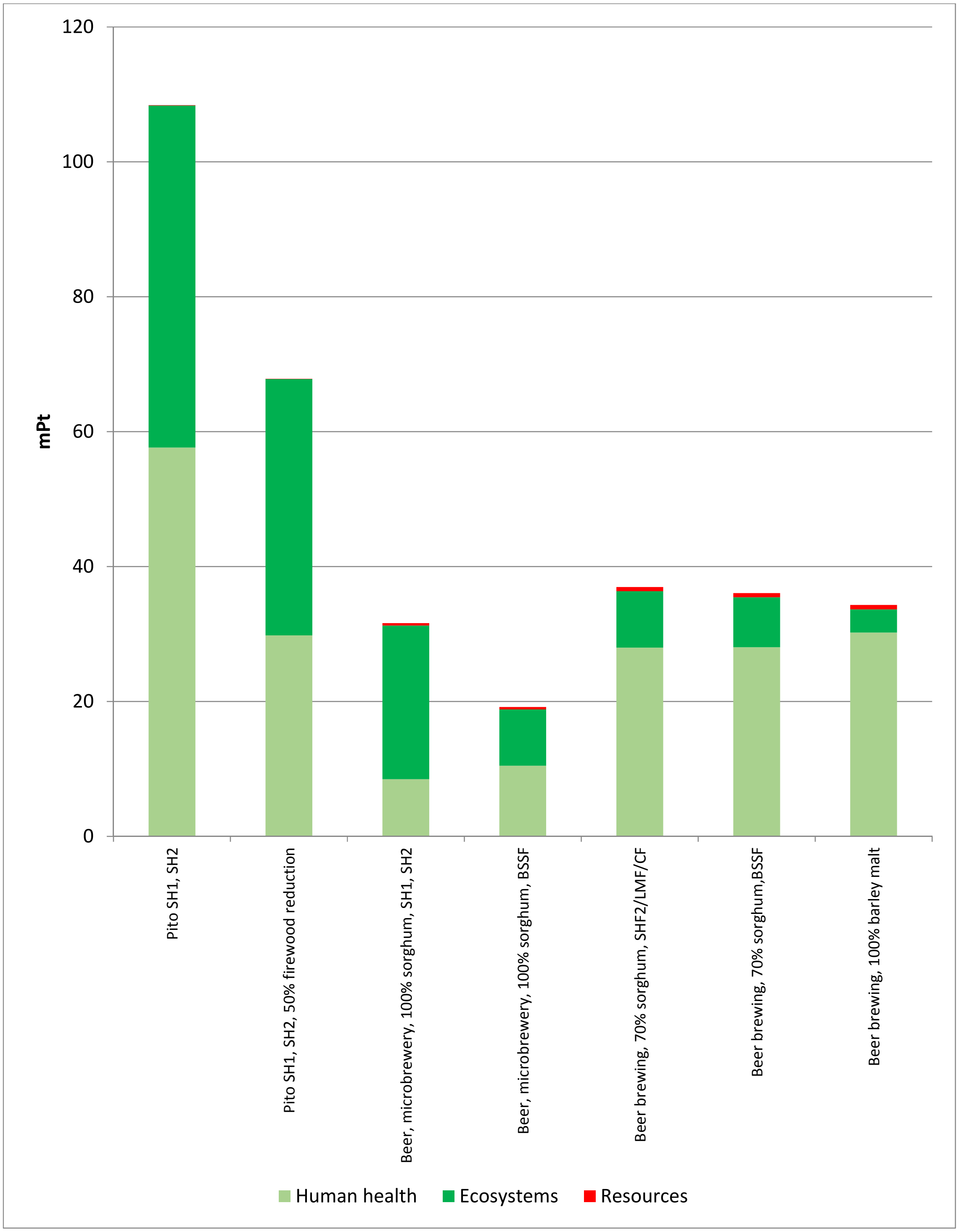

Figure 6-25: Endpoint impacts for each damage category across the three sub-chains.

From left to right: sub-chain 1-SHF1/SHF2, sub-chain 2-SHF1/SHF2 (50% firewood), sub-chain2-SHF1/SHF2, sub-chain 2-BSSF, sub-chain 3-SHF2/LMF/CF, sub-chain 3-BSSF, sub-chain3-barley malt**.**

Source: Authors

Table 6-6: Midpoint impacts for all scenarios (business-as-usual, best-case and benchmark)

Impact category	Unit	Pito SHF1, SHF2	Pito SHF1, SHF2, 50% firewood reduction	Beer, microbrewery, 100% sorghum, SHF1, SHF2	Beer, microbrewery, 100% sorghum, BSSF	Beer brewing, 70% sorghum, SHF2, LMF, CF	Beer brewing, 70% sorghum, BSSF	Beer brewing, 100% barley malt
Global warming	kg CO2 eq	3,4518	1,7608	0,2201	0,2781	0,6680	0,6705	0,7063
Stratospheric ozone depletion	kg CFC11 eq	4,03E-06	2,71E-06	1,35E-06	2,85E-06	1,66E-06	1,73E-06	2,07E-06
Ionizing radiation	kBq Co-60 eq	5,25E-04	5,16E-04	7,06E-03	7,66E-03	1,80E-02	1,80E-02	2,17E-02
Ozone formation, Human health	kg NOx eq	3,17E-03	1,65E-03	5,08E-04	4,73E-04	1,89E-03	1,88E-03	2,17E-03
Fine particulate matter formation	kg PM2.5 eq	3,20E-04	1,90E-04	3,39E-04	4,32E-04	1,43E-03	1,44E-03	1,58E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	5,01E-03	2,58E-03	5,22E-04	4,88E-04	1,92E-03	1,91E-03	2,20E-03
Terrestrial acidification	kg SO2 eq	1,10E-03	6,68E-04	9,80E-04	1,66E-03	3,93E-03	3,97E-03	4,55E-03
Freshwater eutrophication	kg P eq	5,03E-03	5,03E-03	4,48E-03	1,57E-03	1,33E-03	1,13E-03	1,35E-04
Marine eutrophication	kg N eq	2,58E-07	2,48E-07	3,00E-06	3,50E-06	7,83E-05	7,84E-05	2,37E-04
Terrestrial ecotoxicity	kg 1,4-DCB	1,98E-02	1,91E-02	4,82E-01	5,29E-01	1,20E+00	1,20E+00	1,43E+00
Freshwater ecotoxicity	kg 1,4-DCB	1,76E-04	1,75E-04	7,05E-03	7,50E-03	9,71E-03	9,73E-03	1,08E-02
Marine ecotoxicity	kg 1,4-DCB	2,76E-04	2,69E-04	9,26E-03	9,90E-03	1,40E-02	1,40E-02	1,56E-02
Human carcinogenic toxicity	kg 1,4-DCB	6,31E-04	6,30E-04	8,24E-03	8,66E-03	1,61E-02	1,61E-02	1,70E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	4,90E-03	4,86E-03	8,31E-02	9,70E-02	2,81E-01	2,82E-01	2,85E-01
Land use	m2a crop eq	8,6648	6,6750	4,1262	1,3996	1,2423	1,0560	0,3014
Mineral resource scarcity	kg Cu eq	1,20E-04	1,20E-04	8,26E-04	1,26E-03	1,63E-03	1,65E-03	1,75E-03
Fossil resource scarcity	kg oil eq	1,49E-02	1,26E-02	1,23E-01	1,31E-01	2,32E-01	2,32E-01	2,46E-01
Water consumption	m3	4,51E-03	4,51E-03	1,78E-02	1,79E-02	9,33E-03	9,34E-03	1,05E-02

6.4.4 Comparisons of results with evidence/data from literature

Comparisons with LCA results obtained under different conditions, with different system boundaries and assumptions –among other variables– is not straightforward and often not correct. Nevertheless, an attempt was made to check the results obtained in this study against those of literature.

A large number of sorghum value chain LCA studies are concentrated on Carbon Footprint of fibre sorghum use for energy purpose from sorghum biomass. These studies were focused on the entire supply chain and therefore show results for the final product (environmental impacts associated with energy production from biomass), while breakdown of results for the cultivation phase is missing. Nevertheless, one single study carried out in the USA, based on a large sample designed to represent the entire U.S. sorghum industry43 focused on sorghum cultivation from cradle to farm gate and evaluated carbon footprint. The results of this study show a total carbon footprint of 0.25 kg CO2 eq per kg sorghum at farm gate, with a standard deviation of 0.1 kg CO2eq per kg sorghum for all farmers in the sample and a range from 0.05 kg CO2eq up to 0.74 kg CO2eq per kg. These values are in line with the results obtained in this study. The weighted average value of the global warming indicator (midpoint) was 0.215 kg CO2 eq/kg of grains. The range estimated within the present study was from 0.15 to 0.44 kg CO2eq/kg of grains (table 6.4), which falls within the range observed in the U.S. Carbon Footprint study.

Regarding the full sub-chains, previous studies on pito could not be found, while beer industry and beer produced in microbreweries were explored by a wide range of studies, mostly in terms of carbon footprint. Life cycle inventory for sub-chain 2, as discussed previously, was based on detailed data. Results of sub-chain 2, in terms of global warming, were compared to those obtained by other authors for beer packaged in kegs. In particular, the cases studied by Cimini and Moresi (2016) included beer distributed in steel kegs, which showed smaller carbon footprint values (0.25 kg CO2eq / L of beer) compared to beer packaged in glass or aluminium cans. In this study, the carbon footprint of sub-chain 2 was estimated at 0.22 kg CO2eq / L of beer, under the business-as-usual scenario with grain provision from SHF1/SHF2.

Regarding sub-chain 3, although the life cycle inventory of the pre-processing and processing stages were elaborated on the basis of literature data, some of the data used in this study are specific to this sub-chain, in particular regarding transport distances of barley malt from Europe and of sorghum grains from the northern regions of Ghana. Even considering the different raw material (70% sorghum) with respect to those of other studies mainly focused on carbon footprint of malted barley beer, the results for sub-chain 3 are in line with those to be found in literature. The three scenarios evaluated in this study varied slightly in terms of carbon footprint. Indeed, results were 0.68, 0.67 and 0.71 kg CO2eq / L of beer for the business-as-usual, best-scenario and benchmark scenario respectively. These values are in line with the most recent studies (Table 6.7). Among these studies, only the paper by Amienyo and Azapagic (2016) shows cradle to brewery-gate results. It is important to highlight that even though the present study adopted only a few values from Amienyo, including them in the LCI (fuel, steam, auxiliary materials for the brewing stage), there is a significant alignment of the results in terms of global warming potential.

Within several environmental product declarations (Carlsberg® 2016, Tuborg® 2016, Angelo Poretti® 2016, Kronenbourg®, 2016) the global warming potential was calculated for beer packaged in glass bottles. The results ranged from 96 to 121 kg CO2eq / L. It is worth noting that these cradle to grave studies, included large distribution, retail and final disposal.

[43] *Agricultural Market Research - The Carbon Footprint of Sorghum , SGS North America (Société Générale de Surveillance), 2015.*

Table 6-7: Comparison of the sorghum VC LCA results with some values from literature.

Results for this study are in this order: sub-chain 2, business-as-usual (BAU), best-case (BC); sub-chain 3, business-as-usual (BAU), best case (BC) and benchmark scenarios (BM).

Product	Impact category	Value	Unit	Source
Beer-sub-chain 2 (18 L keg) BAU	GWP (midpoint)	**0.22**	kg CO_2eq / L	this study
Beer-sub-chain 2 (18 L keg) BC	GWP (midpoint)	0.27	kg CO_2eq / L	this study
Beer-sub-chain 3 (625 glass bottle) **BAU**	GWP (midpoint)	**0.67**	kg CO_2eq / L	this study
Beer-sub-chain 3 (625 glass bottle) BC	GWP (midpoint)	0.67	kg CO_2eq / L	this study
Beer-sub-chain 3 (625 ml glass bottle) BM	GWP (midpoint)	0.71	kg CO_2eq / L	this study
Beer (33 ml bottles)	GWP	0.72	kg CO_2eq / L	Amienyo & Azapagic, 2016
Beer (several formats)	GWP	0.25 - 0.74*	kg CO_2eq / L	Cimini and Moresi, 2016
Beer (6-bottle pack)	GWP	1.07	kg CO_2eq / L	Climate conservacy (2008)**

*This variation depends on packaging format. The lower value refers to kegs; the highest refers to glass bottles. System boundaries is cradle to beer distribution centres. Retail stage is excluded.
**The Carbon Footprint of Fat Tire® Amber Ale (cradle to retailer, with details of each stage). The value in the table excludes retail –total value reported in the original source is 1.5 kg CO2 eq / L–). The reference is a 6-glass bottles pack of 355 ml capacity each, weighing 568 g/L. This mass is larger compared to the 440 g of glass/L assumed for the 625 ml bottle of study. Part of the higher Carbon Footprint of the Fat Tire® beer could be attributed to this difference. Indeed, if retail stage (28% of total emissions) should be excluded, packaging would be by far the largest source of emissions in this study (30%).

6.4.5 Uncertainties and robustness of results

Data collected for the cultivation phase are reasonably robust. They are the result of a considerable number of interviews with several stakeholders, and in particular with a significant number of farmers. Overall, the lead and medium farmers and the commercial farmers who provided information on agricultural practices represented over 4,000 smallholder farmers. Nevertheless, within an LCA framework, it is important to keep in mind the sources of uncertainties in the interpretation of results and conclusions. The main uncertainties are as follows:

- Data of the life cycle inventory (LCI) are based on information provided mostly through oral communications from memory recall and not documented records by farmers and brewers, a situation which can lead to inaccuracies.
- Default emission factors and factors derived from literature are used for the calculations of N_2O emissions, leaching and erosion.
- The absence of primary data in the life cycle inventory of the industrial brewery has led to the compilation of a generic LCI, applicable to any industrial brewery (except for the specific information contained in this study on transport of raw materials, from EU to Ghana and from the cultivation areas to the brewing site).
- A complete characterization of wastewater from malting and brewing is missing (only data on COD and Phosphate for wastewater from breweries was available). This might lead to underestimations of the impacts of wastewater, which in the case of pito and micro brewing is discharged untreated;
- Generic data from LCI databases have been used for background processes such as vehicles used for transport, which in the database represent types of vehicles mainly used in Europe.

Despite the above, data quality can be deemed reasonable, considering the time-frame of this study. Primary data for sub-chain 3 remained undisclosed, which led to the compilation of the LCI of the core processes using literature data. This has drawbacks, of course, but also advantages.

The main drawbacks are that LCI data for the core phase of sub-chain 3 remain generic, and that the process of compiling an LCI by means of an extensive literature review is more time-consuming than collecting primary data from the source.

The main advantage is that using secondary LCI data in line with industry-wide averages provided the opportunity to generate a scenario that is applicable to any player interested in a screening of the environmental implications of a shift from barley malt brewing to brewing with sorghum grains.

6.6 Conclusions: environmental sustainability of sorghum VC in Ghana

In order to answer to the three core questions regarding the environmental impacts of the sorghum value chain in Ghana on the three damage categories of Human health, Ecosystem quality and Resources, an up-to-date LCA study was carried out for the main sorghum sub-chains in Ghana: including production and utilisation in brewing *pito* as well as alcoholic (beer) and non-alcoholic beverages on semi-industrial and industrial scales.

Sorghum products were evaluated from cradle-to-brewery gate. The results were expressed per 1 L of each product, plus packaging at the brewing site. The life cycle of the products consisted of four main stages: 1) agricultural production (cradle-to-farm-gate); 2) cleaning and sorting including transport from field to warehouse; 3) transport to the brewing site; 4) malting, brewing and packaging. Four different groups of farmers were identified after considering the size and the organization of farmers: (1) SHF1 and (2) SHF2 smallholders with no inputs and low inputs level respectively; (3) LMF lead and medium-scale farmers and (4) CF commercial farmers.

The environmental inventory was based on data collected during two field missions in Ghana where farmers and other stakeholders related to the agricultural sector, representing ca. 4,000 farmers were interviewed. Primary data of the stage at the warehouse, malting of sorghum grains, milling and brewing were gathered from *pito* brewers and from a local brewmaster. Life cycle inventory of the processing phases (malting and brewing) of the industrial brewery sub-chain was derived from literature, since primary data remained undisclosed. Data and information were also gathered from surveys conducted by local enumerators on behalf of the team in October 2019 in the following areas: Wa and Tamale (farmers, traders, *pito* brewers), Accra and Tema (*pito* brewers). However, a full representativeness cannot be claimed for the two value chains for which primary data were available, since information were provided mostly through oral communications by farmers and brewers, thus with an increased risk of inaccuracies.

The processing phase of microbrewery is accurately represented in this study. Nevertheless, this sub-chain is only emerging and takes up very small quantities of sorghum grains, compared to other uses in the value chain. It is worth noting that despite the small scale of operation, microbrewing represents a very interesting sub-chain. It produces beer from 100% malted sorghum (not mixed with other grains). This is a niche product with an important potential market among consumers who, for health reasons, need to keep a gluten-free diet.

An endpoint assessment of the impacts in each damage category was carried out with the ReCiPe 2016 method. For all the products, main impacts are due to ecosystem quality and human health, while Resource showed very low impact in all products. The contribution analysis of the life cycle stages revealed that, depending on the chain, the main contribution derives from a different stage: firewood extraction and combustion in sub-chain 1, cultivation in sub-chain 2 and packaging material in sub-chain 3.

In Sub-chains 1 and 2, cultivation had a major contribution in resources and ecosystem quality (around 50% in both). Major contribution originates also from firewood extraction and combustion for brewing. In terms of human health quality, 98% of the impact is derived from the firewood extraction and combustion for the brewing process (Figure 6.26).

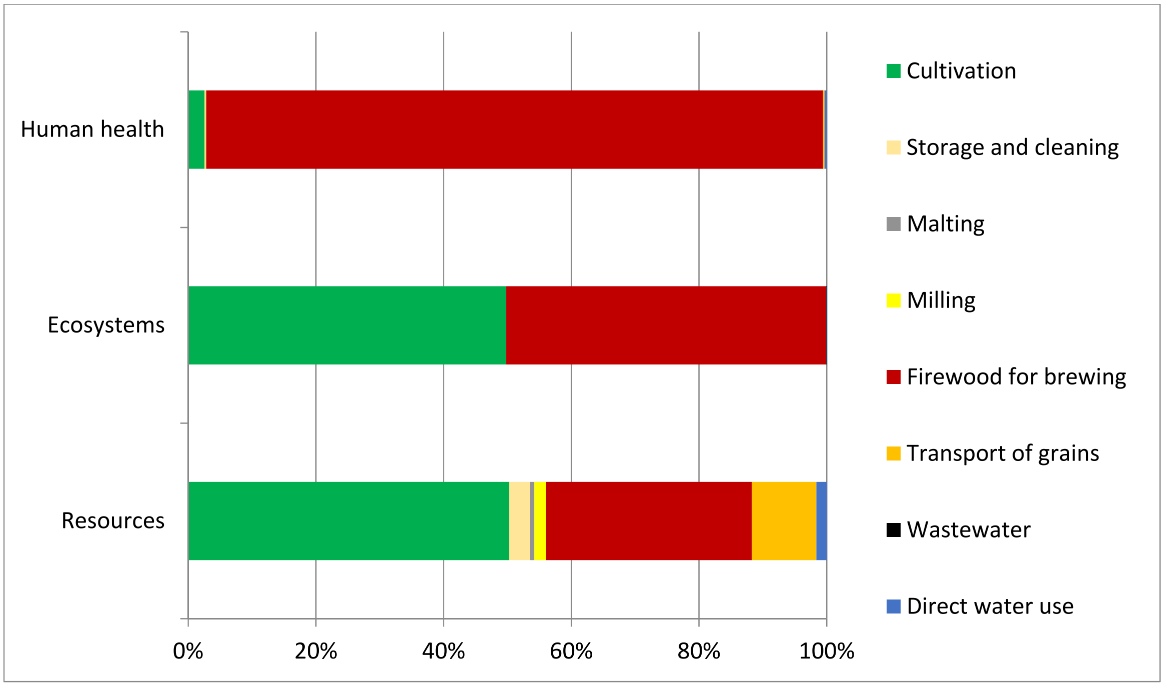

Figure 6-26: summary showing the shares of each stage of the pito sub-chain (sub-chain 1, SHF1/SHF2 BAU scenario) in the three endpoint areas of protection.
Source Authors

Considering that the alternative scenarios (reduction of firewood use, BSSF and combination of both) affect the two stages with major contributions, and considering the three areas of protection, there is large room for improvement in the *pito* value chain. In particular, a wide adoption of the oven technologies seems to be feasible, since the technology is already available in Ghana and some *pito* brewers have already adopted it.

In sub-chain 2, cultivation had a major contribution in the ecosystem quality (98%). The main contribution to the other two areas of protection (resources and human health) is generated at the brewery, being energy –fossil fuel and electricity– the main contributor (83% and 45% in terms of resource and of human health, respectively). A large consumption of water at the brewery (15 L / L of beer) makes its contribution to the human health area almost as important as that of cultivation (13% and 15% respectively) (Figure 6.27).

The alternative scenario for sub-chain 2, i.e. the introduction of the best scenario of sorghum farming (BSSF), affects mainly the ecosystem quality. Considering that the energy efficiency of a small-scale industry is often difficult to improve (the microbrewery has a production of only 20,000 litres / year), there is hardly space for improving this aspect. Water use at the brewery is high (15 L /L of beer –the research by Cimini and Moresi revealed values of water consumption up to 19 L / L for microbreweries–), therefore there might be room for improvements in this area, but they cannot be simulated within this study since that would require also to perform simulations of technological changes in the brewing process, which is out of the scope of the present study. This also applies to the use of auxiliary materials: detergents and liquid CO_2 mixed with beer. The latter is not an external input in industrial-scale breweries, operating with volumes that allow them to recover CO_2 from the fermentation process, but cost-efficient technologies for CO_2 recovery at small scale are not available.

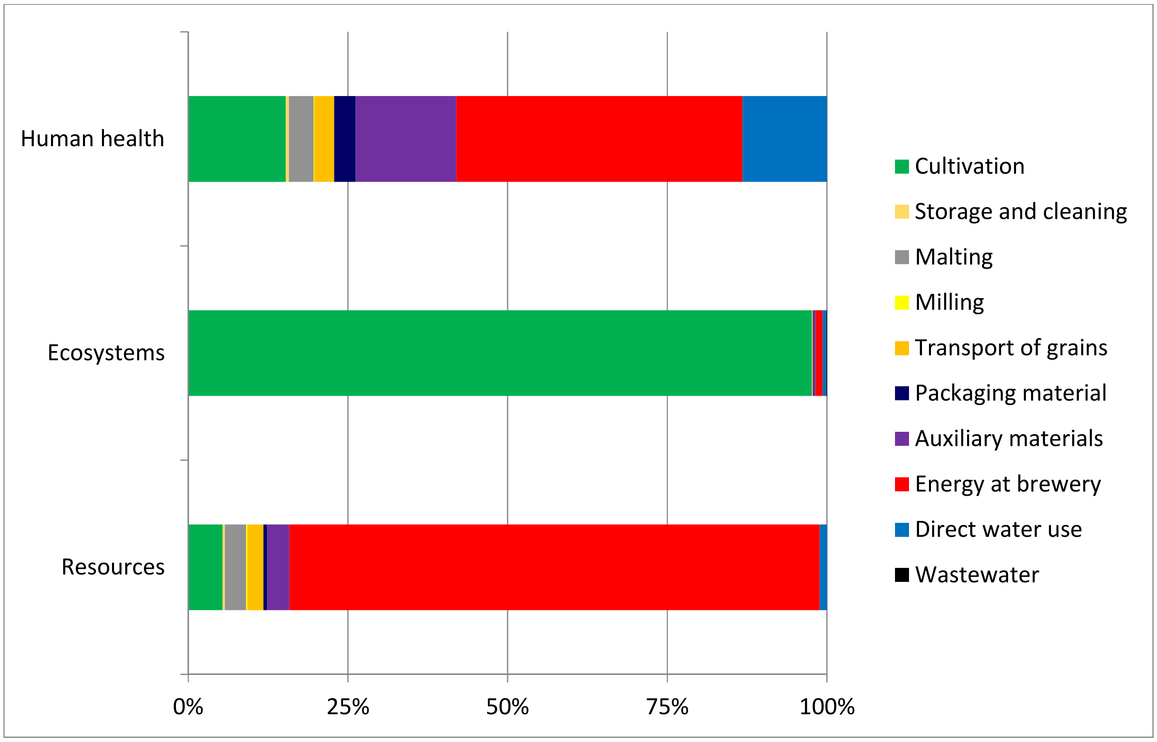

Figure 6-27: summary showing the shares of each stage of sub-chain 2(sub-chain 2 supplied by SHF1/SHF2) in the three endpoint areas of protection.
Source: Authors

In sub-chain 3, cultivation had a major contribution in the ecosystem quality (59%) (Figure 6.28). The main contribution in the other two areas of protection (resources and human health) is linked to the core stage, being glass packaging and energy –fossil fuel and electricity– the main contributors. In terms of resources damage, packaging and energy contributions are 55% and 32% respectively and in terms of human health, 74% and 8% respectively. It is worth to highlight that the use of secondary data for the malting, milling[44] and brewing processes excluded the possibility to tailor the life cycle inventory according to the specific characteristics of a given plant. This regards in particular the presence/absence of on-site power generation. An on-site power generation (i.e. from anaerobic digestion of spent grains) might largely ameliorate impacts within this sub-chain. Therefore, even if such types of facilities are not yet available, information on intentions of integrating them in the process system might have provided room for interesting scenarios analyses. Furthermore, since glass bottles production has such a large impact, in case a packaging reuse through a system of returnable containers is in place, impacts from glass bottles production can be largely ameliorated. According to the information gathered during the field missions, bottles reuse was in place until recently in Ghana through a deposit-refund system[45], but lately this virtuous system has been replaced by a retail system based on non-returnable containers.

For this sub-chain, under the alternative scenario (grain production by BSSF) it is assumed a more efficient crop management of part of the SHF2, leading to an increase in yields, which can potentially improve land use and therefore ecosystem quality.

[44] *Malting impacts only in 1% in terms of resources damage while no further relevant impacts are observed for these two processes.*
[45] *Based on the collection of a monetary deposit on beverage containers at the point of sale to ensure that the packaging can be returned to the brewery, washed and refilled.*

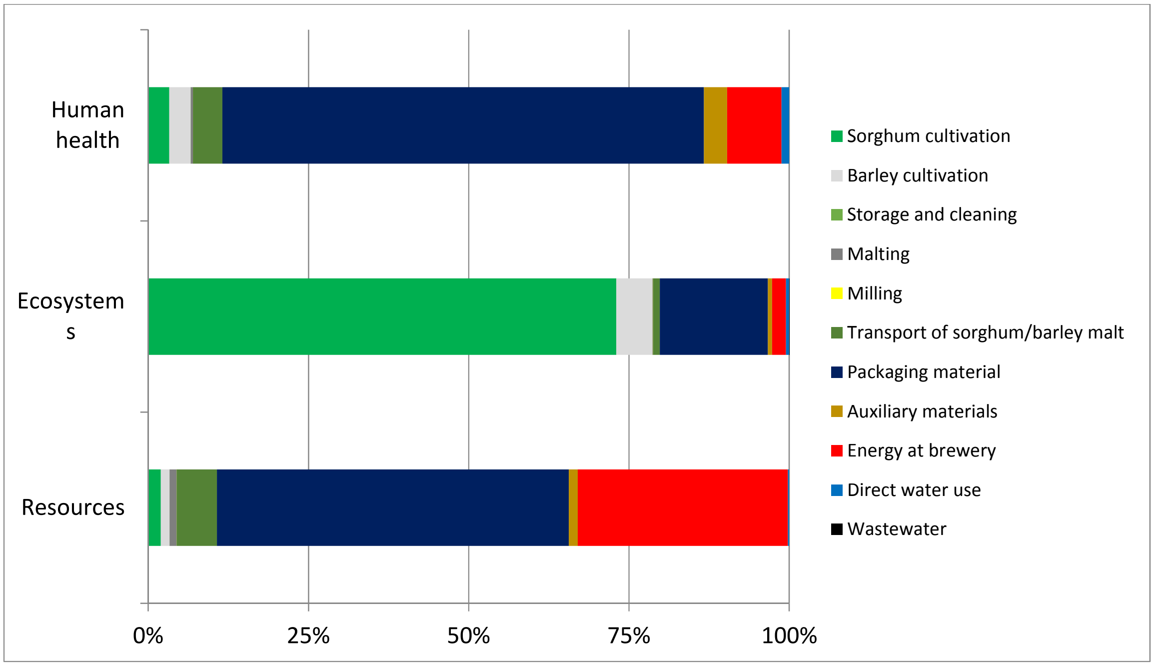

Figure 6-28: summary showing the shares of each stage of sub-chain 3 (sub-chain 3 supplied by SHF2, LMF and CF BAU scenario) in the three endpoint areas of protection.
Source: Authors

As it can be seen from the three sub-chains, the milling operation has negligible environmental impacts, therefore it can be concluded that for the milled grains there is no significant contribution of impacts from this operation. For this reason, and for the sake of simplicity, results for milled grains are not explicitly shown. Due to the very low environmental impacts of milling (and of the only two intermediate processes between the grain production at farm and the milling, which are transport of grains and cleaning & sorting), the environmental impacts of grains at farm-gate can be assimilated to those of milled grains.

This LCA study of sorghum-based products in Ghana provided an up-to-date reference regarding their environmental performance and allowed to identify margins of improvement for all three sub-chains. Regarding the processing phase, this is particularly true for sub-chain 1. Indeed, potential damage to ecosystems due an extensive land use, associated with low yields and also with land use change due to forest degradation triggered by firewood use, prevents sub-chain 1 from being environmentally sustainable. This is also true for the potential damage to human health associated mainly with high levels of global warming potential, derived from the use of firewood. Therefore, the introduction of ovens for *pito* brewing can have very positive impacts both from human health and ecosystem quality perspectives. Indeed, it would contribute to the reduction of firewood consumption, of direct exposure of brewers to harmful open fire pollutants and to the reduction of forest degradation.

The environmental sustainability of sub-chain 2 is in line with what can be expected for a small scale brewery. It was shown that an improvement in yields at farm gate (BSSF) would further improve the environmental performance of this sub-chain.

Regarding sub-chain 3, as it can be expected, by using inventory data based on industry-wide averages, the resulting environmental performance could not differ much from those found in literature. Nevertheless, it is worth highlighting that even considering the assumption of using sorghum produced locally in Ghana, which belongs to this specific study, the environmental performance of industrial beer production remained in line with the results from literature. The simulation carried out considering the use of barley malt from EU origin alone allowed to show that the potential environmental impacts of brewing with sorghum from northern Ghana does not differ much from those derived from brewing with imported barley malt.

7 TRANFORMING GHANA'S SORGHUM VALUE CHAIN: OPTIONS

7.1 Introduction

The analysis reported in the preceding three respective chapters shows that the sorghum value chain in Ghana currently makes an important contribution to the wellbeing of households in the regions where its production is concentrated as well as to the overall national economy. It remains an important food crop and offers profitable income-generating opportunities for range of actors, including especially smallholder farmers, small-scale grain aggregators and traders and pito brewers. The analysis further shows that it is a socially sustainable value chain in which growth is inclusive as most of the activities in the chain are dominated by small and medium-scale actors. Women in particular are well-represented at the level of production and almost exclusively dominate pito brewing and grain retailing. There is evidence from the social analysis that participation in the value chain offers women a degree of financial independence and the income generated is crucial in household investment in children's education, health care and better housing. In addition, it emerged that the chain makes significant contribution to Ghana's agricultural GDP, rural employment creation and public finances.

Despite the above, it is apparent that the performance of the chain and its positive impacts can be significantly optimised in the short to medium term if potential "low-hanging" opportunities for transformation are exploited. These opportunities include initiatives to boost farmers' productivity and fostering investments in available, low-cost innovations in downstream activities such as pito brewing. Such investments are actually expected to help lower the environmental effects of key activities at certain levels in the value chain. The LCA of sorghum products concludes that the main impacts resources are relatively very low but notes that the main contribution derives from firewood extraction and combustion in pito brewing. Cultivation of the crop also has a major contribution in resources and ecosystem quality (around 50% in both) but the projection is that improving farm productivity will reduce the effects, including easing pressure to expand area under cultivation.

The alternative scenarios under which the value chain can be transformed as well as major risks which can hamper this are the focus of discussions in this chapter. It includes measures to boost grain output through increased farm yield and lowering postharvest losses. Options to ensure that output growth is sustainable are also explored as is the potential impact of a pandemic such as COVID-19.

7.2 Boosting farmers' productivity

Low productivity at the level of grain production is one of the main factors hampering sustained growth in the sorghum value chain. A two-pronged strategy to address this is explored and reported below. It consists of increasing average yield obtained by smallholder farmers and also reducing the high level of postharvest losses which characterise their operations. These are discussed below.

7.2.1: Enabling smallholder farmers to obtain increased yield

Data from surveys conducted during this study and confirmed by experts at SARI, the average yield obtained by SHF1 sorghum farmers is about 0.65 tonnes per hectare whilst the SHF2 farmers get 0.85 tonnes per hectare. These yields, reported in Chapter 4, are well below the official estimates of the national average yield of sorghum, which is about 1.2 tonnes per hectare. The gap between what farmers reportedly obtain and the official yield estimates is about 46% for SHF1 farmers and 29% for SHF2 farmers.

The gap exists partly because the official estimates assume that farmers use inputs such as improved seed, fertiliser pesticides at the recommended rates in growing sorghum. However, it emerged from our survey that SHF1 farmers do not plant improved seed varieties or apply fertiliser on their sorghum farms. This is despite the fact that they can access subsidised inputs under the Government's PFJ. The scenario explored, therefore involves the following:

a. Empowering SHF1 sorghum farmers to acquire inputs under PFJ for one acre (or 0.4 hectares) of land cultivated with sorghum, thereby raising their overall output to 0.85 tonnes per hectare (i.e. by 31%); and
b. Doubling the assistance provided to SHF2 farmers to cover inputs requirements for two acres (or 0.8 hectares) of land cultivated with sorghum, making it possible for them to obtain average yield of about 1.02 tonnes per hectare, an increase of about 20%.

The scenario analysis regarding yield increase for sorghum grain farmers focuses on uptake of available inorganic fertiliser, improved seed and pesticides. This is not because the team discounts alternative technologies including utilisation of organic fertiliser such as cattle manure, mainly because the team found no evidence from the field study that such technologies have been adopted by sorghum farmers (see Section 6.3.1).

Furthermore, enabling the target farmers to access inputs available under PFJ will ensure equity as they are more qualified to receive subsidies than better-endowed farmers such as medium-scale and commercial farmers. This will require addressing the binding constraint most smallholder farmers face in accessing input, that is severe liquidity constraints, which tend to be prevalent in their households during the planting season.

The case of SHF2 farmers covered in this study shows that it is possible to develop financing packages targeting smallholder farmers in order to boost their uptake of available inputs. Models such as the MOAP-supported Inputs Revolving Fund in the Upper West Region and the Outgrower and Value Chain Fund (OVCF) in the Upper East can be scaled up for this purpose. Private financial intermediaries consulted during the study showed interest in participating in this, especially if it is structured around supplies to large-scale offtakers such as the industrial brewery. Extending this form of financing to SHF1 farmers will require exploring participation by community-based rural and community banks. It will also be beneficial to explore how other ongoing initiatives which foster de-risked agricultural lending can be exploited. Examples include agricultural insurance under the Ghana Agricultural Insurance Pool (GAIP) and instruments being developed by the Ghana Incentive-based Risk Sharing System for Agricultural Lending (GIRSAL) Programme to minimise default risk in agriculture.

7.2.2 Reducing postharvest losses

The other option explored for purposes of increasing sorghum grain available to farm households for sale and/or consumption focuses on reducing postharvest losses (PHL). Currently, PHL in the sorghum value chain is estimated at about 12%. Halving this rate of PHL in the subsector will be consistent with commitments the Government of Ghana has made under the African Union's Malabo Declaration of 2014. Commitment 3.b of the Declaration requires African governments to "halve the current levels of postharvest losses by the year 2025"[46]. This objective is also consistent with the UN's Sustainable Development Goal (SDG12.3), which encourages countries to reduce food losses along production and supply chains by about 50% by 2030[47].

It has been stressed that achieving these goals will produce positive food and nutrition security impacts as well as potentially enhance household incomes. The unimodal rainfall pattern in Northern Ghana implies that field drying of the grain is technically feasible. However, evidence reported in this study (in Section 3.4.1), there has been an increase in the incidence of late rains, impeding this process and triggering mouldiness and increased incidence of aflatoxin contamination. The challenge is being met with the use of tarpaulin for off/on-farm drying after harvest (see Figure 3.8).

7.2.3 Anticipated impact of proposed interventions

Table 7.1 below provides highlights of the impact of the proposed support to enable smallholder farmers take up yield-enhancing inputs and also adopt improved grain drying system which reduces postharvest losses. The average yield obtained by SHF1 farmers rises by 31% from 0.65 to 0.85 tonnes per hectare. Similarly, the yield obtained by SHF2 farmers also rises from 0.85 to 1.02 tonnes per hectare, an increase of about 20%. As a result total sorghum grain output is projected to rise by just over 25% to about 351,300 tonnes. Though the projected increase appears steep, it is within the average produced in Ghana during the second half of the 1990s and close to 10% below the peak of 387,000 tonnes produced in 1998.

Table 7-1: Anticipated impact of support for uptake of inputs by smallholder sorghum farmers

Particulars	Current level	Projected level	Change
Average yield for SHF1 farmers (tonnes/ha)	0.6	0.85	31%
Average yield for SHF2 farmers (tonnes/ha)	0.85	1.02	20%
Total sorghum grain outputs (tonnes)	278,000	351,300	26%
Total sorghum grain sold (tonnes)	151,910	197,600	30%

[46] *Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods*
[47] *http://www.fao.org/sustainable-development-goals/indicators/1231/en/*

Farm household consumption of grain (tonnes)	92,875	132,600	43%
Per capita sorghum grain consumed (bags)	8.5	12.0	41%
Postharvest loss by volume (tonnes)	33,045	21,100	-36%

7.2.1.1 Rise in sorghum productivity can boost smallholder farmers food/income security

The combination of the increase in the yield obtained by smallholder farmers and reduction in postharvest losses is a rise of about 30% in the volume of sorghum available to be sold into the market. As shown in Table 7.1, postharvest losses at the farmers' level declines by about 36%, implying savings of 11,945 tonnes of grain with market value of GHS 12.9 million (i.e. US $2.69 million or €2.38 million). Sorghum grain available for consumption by the farm households is also projected to increase by over 40%. Smallholder households, on the average would have available to them 12 bags (or 0.6 tonnes) of sorghum grain for consumption instead of 8.5 bags.

The impact on household income from the proposed inputs uptake support is quite substantial, as shown in Table 7.2 below. The sorghum-based income which SHF1 farmers can obtain almost doubles to an estimated at GHS 412.50 (equivalent to $86 or €76), per annum per farmer. We assume that the SHF1 farmers will continue to allocate only 30% of the land they cultivate to sorghum (see Table 3.2). Based on this, we project that their annual farm income if they commit 100% of their cultivated land to sorghum under proposed scenario will be about GHS 1375 ($285 or €255), which is slightly above the national poverty line, estimated at GHS 1,315 in 2017. The foregoing, therefore, shows that this form of support makes it technically feasible for poor SHF1 farmers to escape poverty whilst relying entirely (100%) on sorghum production though it is anticipated that diversification will remain the key strategy for most smallholder farmers.

For SHF2 farmers it is projected that their household income from sorghum production will rise by about 30% to about GHS 800 (i.e. $165 or €150) per annum at current levels of allocation of cultivated land to sorghum. We project that if they commit 100% of their area planted to sorghum with the extra support proposed, they can obtain about GHS 2,000 ($415 or €370) per annum. This implies that for both categories of smallholder farmers, income from sorghum will remain comparatively lower than earnings from the formal sector as the annual minimum wage, estimated in 2018 at GHS 3,065 (or $640 or €565) remains higher.

Table 7-2: Projected operating accounts of producers of sorghum in Northern Ghana (in GHS)

Item/producer	Smallholder farmers (SHF1)	Smallholder farmers (SHF2)	Lead/medium-farmers (LMF)	Commercial farmers (CF)	Sub-total for farmers
Total value of production	**243,789,002**	**155,345,090**	**4,876,161**	**2,042,443**	**406,052,696**
Sales	131,311,248	95,407,577	3,900,000	1,890,690	232,509,514
Self-consumption	100,246,671	51,609,870	448,500	36,594	152,341,635
Subsidies	12,231,084	8,327,643	527,661	115,159	21,201,547
Stock variation	-	-	-	-	-
Intermediate goods and services (total)	**92,453,425**	**57,045,939**	**1,842,370**	**385,524**	**151,727,258**
Seed	-	3,396,958	117,667	25,680	3,540,305
Fertiliser	20,369,471	11,040,114	780,767	170,398	32,360,750
Pesticides	4,092,697	2,218,214	156,889	34,240	6,502,040
Transport	10,761,662	10,759,789	212,931	48,741	21,783,123
Bagging materials	3,955,595	182,629	83,838	18,297	4,240,359
Utilities	-	-	-	4,280	4,280
Ploughing	53,274,000	29,448,235	490,278	83,888	83,296,401
Value added (direct)	**151,335,577**	**98,299,151**	**3,033,791**	**1,656,919**	**254,325,439**
Value of rented land	-	-	-	42,800	42,800
Value of hired labour	53,919,153	43,693,376	1,585,558	440,412	99,638,499
Financial charges	21,426,138	13,753,231	370,944	83,788	35,634,101
Local council levies	573,549	692,979	70,600	21,400	1,358,528
Taxes/duties	-	-	-	-	-
Depreciation	3,996,059	2,526,488	83,396	85,600	6,691,543
Net profit	71,420,678	37,633,077	923,293	982,919	110,959,967
Sorghum income per household (GHS)	412.50	797.65	2,637.98	245,729.75	
Annual income (100% sorghum) (GHS)	1,375.00	1,995.00	4,396.67		

7.3.2.1 Productivity gains and generate positive environmental impact

It was reported in Chapter 6 that increasing output through yield optimisation rather than expanding acreage under cultivation helps to reduce overall emissions in the use of sorghum for brewing and other processing activities. This evidence is consistent with the conclusions by Burney et al. (2010), who demonstrate that increase in crop productivity from 1961 to 2005 helped to avoid up to 161 Gt of carbon emissions and were a relatively cost effective for mitigation, despite use of inputs that increased emissions. Similarly, Vlek et al. (2004) found that increase in yield resulting from a 20% rise in the utilisation of fertilizer in the production of rice, wheat, and maize can take almost 23 million hectares out of cultivation without changing the level of production.

7.3.2.2 Gains in farmers' productivity to boost downstream sorghum value chain activities

It is anticipated that the additional 45,690 tonnes of sorghum grain which will be marketed as a result of the above supply-boosting propositions, will boost activities downstream actors such as commercial and pito brewing, grain processing and grain retailing. It is assumed that about 44% of this grain (about 20,000 tonnes) will be supplied to industrial breweries, microbrewers and medium-scale grain processing enterprises. This grain will be channelled mainly through sub-chain 3, with large-scale aggregators playing a key role. Another 46% (about 21,000 tonnes) of the additional supply will be channelled to pito brewers through sub-chain 2, involving small/medium-scale aggregators who will be purchasing directly from producers rather than from micro-scale rural aggregators or collectors. The remaining 4,690 (about 10% of the supply) is expected to be mobilised directly by the small/medium-scale aggregators and sold through large-scale wholesalers to grain retailers in urban markets.

There are two mutually beneficial reasons for marketing through these distribution channels. First, it ensures that the downstream actors can arrange consistent supply of good quality grains, thereby enabling them to scale up their operating capacity. On the other hand, it makes it possible to anchor financing packages to grain procurement agreements involving offtakers such as the aggregators. This has been demonstrated to be feasible at the level of large-scale aggregators in sub-chain 3. There is also the potential to similarly empower small/medium-scale aggregators building on access to microfinance and traditional production financing by traders. The overall chain-wide impacts of increased grain supply and uptake by downstream actors is discussed in Section 7.3 below.

7.3.2.3 Seed supply systems need to be improved

In addition to packaging finance to enable smallholders access inputs (discussed in Section 7.2.1 above) it is important to address the problem of inadequate supply of viable seed, which is plaguing the value chain. There was recourse to emergency seed imports to mitigate this problem but the results were generally unsatisfactory. For instance, the germination performance of some of the imported seed was reported to be poor. Some of the imported varieties also proved unsuitable for conditions in Northern Ghana. It emerged from our consultations that severe constraints in the form of lack of required human capacity and funding challenges made it difficult for the Savannah Agriculture Research Institute (SARI) to promote stable supply of certified seed. Whilst these needs have to be addressed as a matter of urgency, it is also important for SARI to avoid focusing exclusively on improved white sorghum varieties preferred by commercial brewers and pay equal attention to the red varieties which pito brewers prefer. Furthermore, it has to be stressed that compromising regulatory enforcement in the case of emergency seed imports can be counter-productive as recent cases have demonstrated. In the end, if the viability of sorghum seed becomes uncertain, uptake will be dampened leading to continued reliance on low-yielding landraces.

Table 7-3: Impact of improvements on projected value added by actors in sorghum value chain in Ghana

Item/value chain actor	Direct value added by main actors				Indirect VA contributed by suppliers of goods & services	Total
	Sorghum grain producers	Sorghum traders & distributors	Sorghum processors & brewers	Sub-total		
Value of rented land/storage etc.	42,800	7,385,195	378,315	7,806,310	70,806	7,877,116
Value of hired labour	99,638,499	10,374,300	60,666,690	170,679,489	146,958,552	317,638,041
Financial charges	35,634,101	33,404,194	85,750,000	154,788,295	103,765,750	258,554,044
Local council levies	1,358,528	2,873,880	219,300,000	223,532,408	- 0	223,532,408
Taxes/duties	-	3,333,500	1,954,100	5,287,600	123,047,632	128,335,232
Depreciation	6,691,543	1,557,850	67,878,500	76,127,893	59,591,289	135,719,182
Net profit after tax	110,959,967	43,492,307	314,979,185	469,431,459	131,212,539	600,643,998
Sub-totals	**254,325,438**	**102,421,226**	**750,906,790**	**1,107,653,454**	**564,646,567**	**1,672,300,021**

7.3 Anticipated impact of productivity growth on sorghum value chain

7.3.1: Rapid and inclusive growth in value chain

The projected increase in the volume of sorghum grain sold in the value chain in Ghana is estimated at only 30% but the expected chain-wide impact is likely to be significantly much higher. We have reported above (in Section 7.2.3.1) that sorghum-related household income for smallholder farmers rises steeply in the alternative scenario explored. Total value added generated in the value chain is also projected to rise by almost 65% to about GHS 1.67 billion (equivalent to just over US $345 million or €310 million). Assuming the same base as in 2018, this figure will represent a contribution to agricultural sector GDP of about 3%.

Along with the rise in value added is an over 40% increase in wage earnings attributable to the sorghum value chain and 61% increase in fees for provision of financial services to actors in the chain, including outside suppliers. Though total subsidy injected into the chain via the PFJ rises more than three times, the net increase in contribution to public finance is more than 30%. This is due largely to a 37% rise in total contributions to taxes, duties and local council levies by actors in the value chain.

The growth in the value chain, which is expected to be triggered by increased farm output, results in a 58% growth to income accruing to all actors in the chain. The rise in income for the main actors, that is excluding suppliers of goods and services, is of an even higher order of an estimated 64%. The anticipated growth is also highly inclusive and socially sustainable. This is depicted in Figure 7.1, which shows pito brewers being in the lead by far in terms of their share of income accruing to the main actors in the value chain. They receive an estimated 48% of the income to the main chain actors. The total share of actors' income accruing to small and medium-scale actors is close to 80%. These include smallholder famers, micro, small and medium-scale aggregators as well as pito brewers, who are predominantly women.

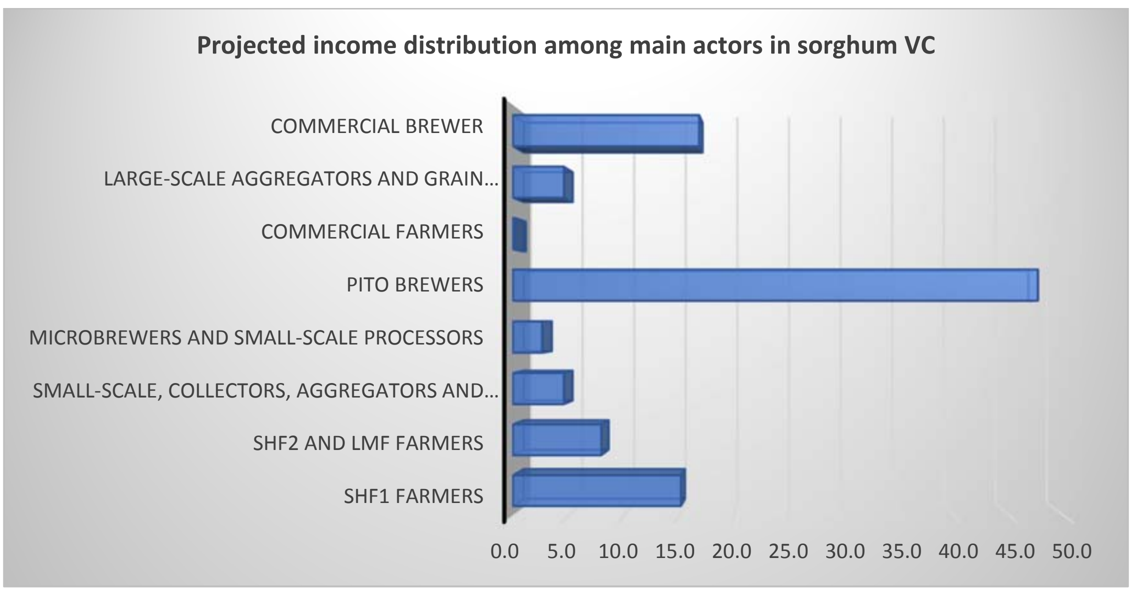

Figure 7-1: Projected income distribution among main actors in sorghum VC

The projected growth is also expected to improve environmental sustainability in the value chain. This is due in part to the impact of increase in yield, mentioned in Section 7.2.3.1, as well as improvements in combustion technology recommended to be adopted by pito brewers (see Section 7.3.2.2 below).

7.3.1.1 Downstream transformation key to sustainable growth

Figure 2.3 shows that growth in sorghum output in Ghana over the decade ending in 2017 was rather erratic. Such a growth pattern is likely to dissuade investors in the value chain, especially those in the formal segments (from grain production through to transformation). Anecdotal evidence from consultations with some of the key actors confirmed the team's assumption that growth in grain output can only be sustained if matched by increased absorption capacity by actors involved in transforming sorghum grain into consumer products. In the next we analyse options to increase offtake capacity and enhance efficiency in downstream transformation of sorghum grain. Similar options to modernise the grain distribution system is analysed Section 7.4.

7.3.2: Boosting grain offtake to sustain value chain growth

At the grain transformation segment of the value chain, three potential areas to drive growth in offtake capacity are explored. These include upscaling of sorghum grain utilisation by breweries, increased efficiency in pito brewing and support to scale up grain processing into food products. The results of the analysis are reported below.

7.3.2.1 Increase in offtake by formal breweries

The study confirms that uptake of sorghum grain in industrial brewing has had a significant transformative effect on the local sorghum value chain. As reported in Chapter 4, the contribution to total value added and public finances generated in the value chain by the brewery industry has been substantial. Local purchase of sorghum grain for industrial brewing has also catalysed the emergence of a formal distribution channel which assures consistent delivery of quality grain and created a foundation around which inputs finance to SHF2 farmers has been developed.

This positive impact can be sustained and even scaled up if the volume of locally-sourced sorghum grain is maintained or rises. From consultations during the study, it emerged that sorghum grain offtake for this purpose could be scaled up from the 2018 level of 18,000 tonnes to between 35,000 tonnes to 40,000 tonnes per annum in the near future. We used the lower volume of 35,000 tonnes in our scenario analysis. Some key stakeholders, however, expressed concern about the current situation where there is only one major offtaker in Sub-chain 3. This concern materialised when the COVID-19 pandemic affected operations of this offtaker, an issue which we analyse in more depth in Section 7.5.

Diversification of formal offtake is one of the strategies worth considering in an attempt to ensure sustained growth in the value chain. Though this is unlikely to have proved effective in mitigating the impact of COVID-19, it is anticipated that during "normal" times the entry by another major offtaker in the industry would ease the concerns about relying on a sole buyer. For this reason, the team considered the potential of encouraging uptake of the grain by Accra Brewery Limited (ABL). It was, however, not possible to explore this option because of difficulties in securing interviews with the management of ABL.

Another option in terms of formal offtake of sorghum grain by formal breweries is to promote the emergent microbreweries (see Section 3.3.3). The concept of microbrewing in Ghana has been proved as technically and financially viable by an Accra-based brewer. This is particularly because the existence of a market for bespoke-branded products tailored to the needs of specific customers and for particular occasions. The team identified potential sources for technical advice in setting up microbreweries, including a retired/experienced brewer and the FRI. However, access to low-cost capital for investment required equipment and other fixed assets remains a major bottleneck in the development of this enterprise.

7.3.2.2 Improved efficiency in pito brewing and marketing of non-alcoholic pito

In our analysis, close to 50% of the additional sorghum grain output which is marketed is allocated to pito brewers. This is mainly because it is the leading user of marketed sorghum grain, currently accounting for about 65% of the marketed crop but the share actually drops to 61% under the new scenario principally because of the increased volume which will be marketed. It is anticipated that pito brewing can sustain the increased volume of grain supplied partly because of the possibility of becoming more cost-efficient and, therefore, more profitable as a result of investing in improved fuel combusting technology which utilises about 50% less firewood. The cost of firewood currently accounts, on the average, for almost 30% of the total operating cost in pito brewing. Hence, switching to modern earthen stoves, which can potentially reduce firewood use and associated cost by about 50%, is expected to produce the following benefits:

- The overall average cost of brewing pito falls from about 72% to 64% of the total value of production;
- As a result the activity becomes more profitable, with average return on turnover rising from 25.6% to 33.7%;
- This leads to increase in average household income from pito brewing by 60% to GHS 40,600 (i.e. $8,440 or €7,410) per annum;
- The incremental annual household income for pito brewers, estimated at GHS 15,300 (i.e. $3,190 or €2,830) is more than five times the upfront cost of the improved earthen stoves (estimated at GHS 3000 or $625 or €560);
- This will make it relatively easy for pito brewers to make the switch in technology, in terms of the period over which the capital outlay required has to be amortised; and
- The combined effects of improved cost-efficiency and scaling up of production is an estimated 45% rise in value added attributable to pito brewing.

The foregoing shows the potential pito brewing to be even more financially sustainable and inclusive whilst contributing significantly to growth in the national and rural economy. Furthermore, as concluded in Chapter 6 (see Section 6.6), introduction of a more fuel-efficient combustion systems (ovens) for *pito* brewing can have very positive impacts from human health and ecosystem quality perspectives.

On the demand side, upscaling of pito production can be even more sustainable if there is increased consumption of non-alcoholic pito. Currently, consumption of non-alcoholic pito discouraged partly because it is difficult to distinguish between the alcoholic and non-alcoholic pito products. The perception in the large Muslim and Christian communities in the North is that encouraging the consumption of non-alcoholic pito can lead to increased drinking of alcoholic pito leading to rising levels of alcoholism. For this reason, the consumption of non-alcoholic pito is discouraged despite the health and nutrition benefits, especially if consumed by children and young adults, as noted in Chapter 5 (see Table 5.5). There is no such opposition to non-alcoholic malt drinks produced with sorghum. It is therefore apparent that packaging the product in a manner which clearly distinguishes it from alcohol pito will boost the market for non-alcoholic pito and needs to be explored.

7.3.2.3 Promoting sorghum grain processing

Boosting sorghum grain processing is another action which can be implemented to catalyse sustainable growth in uptake of the grain. Two key strategic actions are required to achieve this. First, is to ensure that grain supply to the processing enterprises is channelled through a distribution system which ensures consistent supply of quality grain. That system is already emerging in sub-chain 3 and involves the large-scale aggregators who are currently supplying grains to the industrial brewery. We presumed that this will happen by allocating 2,000 tonnes of the additional grain produced to processing enterprises. This issue is further discussed below.

The second strategic action involves enabling grain processing enterprises to comply with the licensing and regulatory requirements for marketing food products in the country. This appears to be a major binding constraint and was cited by the micro-processors consulted as one of the main reasons why they have been unable to scale up their operations. There is evidence that this challenge can be overcome through public investment in incubation hubs for processing grains and other food products and is an option worth considering.

7.3.3 Efficient sorghum grain distribution chain important driver of growth

Table 7.4 shows that sorghum grain transformers (brewers and processors) contribute close to 50% of the increase in value added in the chain resulting from investments which boost grain output and offtake. About 70% of the incremental value added at this level of the chain is expected to be generated by formal and semi-formal grain transformers (e.g. commercial breweries, microbrewers and small/medium-scale processors). This demonstrates the potential of this segment to strategically drive rapid and sustained growth in of the sorghum value chain.

Table 7-4: Projected change in value added in sorghum value chain growth in output and offtake

	Total VA in 2018	Total VA in alternative scenario	Increase in VA	Contribution to total VA increase (%)
Sorghum grain producers	177,920,483	254,325,438	76,404,955	11.6
Sorghum traders & distributors	86,186,444	102,421,226	16,234,782	2.5
Sorghum processors & brewers	425,008,740	750,906,790	325,898,050	49.7
Suppliers of goods/services	326,974,691	564,646,567	237,671,876	36.2
Total from value chain	1,016,090,358	1,672,300,021	656,209,663	

Realising the identified growth potential, however, depends on ensuring a distribution chain which can guarantee consistent delivery of grains which meets officially sanctioned food quality standards. This type of distribution chain is already emerging in sub-chain 3 and consists of the following key elements:

- An aggregation system centred around the LMFs, which enables SHF2 farmers to deliver quality grains to the large-scale aggregators supplying to industrial breweries.
- The farmers have been trained in basic postharvest handling processes and, in some cases, been assisted with the provision of tarpaulins to enable them properly dry grains in order to minimise the risk of Aflatoxin infestation.
- There is also access to small-capacity warehouses (about 50-tonne capacity) to centralise aggregation activities which include use of properly calibrated weighing scales, thereby assuring transparency in the trade.
- Large-scale aggregators are beginning to invest in proprietary storage infrastructure and grain handling services, making it possible to hold stocks and be in a position to deliver on just-in-time basis.

There is need to scale up the capacity at the aggregation level, including enabling them to reach the point where they can take the burden of storage away from end-users such as industrial breweries and other processors. There is also the need to address lack of liquidity in the grain distribution system. An option worth exploring is how the warehouse receipt system (WRS) being promoted by the Ghana Grain Council (GGC) can be made to facilitate collateralisation of stockpiled grains.

7.4 Impact of COVID-19 on sorghum value chain

7.4.1 Incidence of COVID-19 in Ghana

According to World Health Organisation (WHO) data, Ghana currently ranks fourth in Africa in terms of reported confirmed cases of COVID-19 – behind only South Africa, Egypt and Nigeria. However, on the basis of the number of COVID-related deaths, the country ranks 13th in Africa. These figures show that the pandemic, which has had devastating effects globally, is a major health crisis in the country. However, in rural Ghana the rate of COVID infections has been comparatively low. As at mid-August 2020, the five Northern Regions where sorghum production is concentrated had reported only 2.2% of the total confirmed cases of COVID-19 in the country. This is despite having about 18.4% of the national population living in these regions. In contrast, Greater Accra and Ashanti Regions with 35% of the national population accounted for about 75% of the confirmed cases of the virus.

Despite low incidence of the disease in the major producing areas, the sorghum value chain has been affected by some of the actions taken by governments in response to the outbreak. These actions include lockdowns and restrictions on human and vehicular traffic movement; closure of land borders and airports; closure of schools and food markets in urban areas; and controls on the number of people who can congregate for religious and social events (e.g. going to churches and mosques as well as participating in funerals, weddings etc.). The impact of these actions on the sorghum value chain are discussed below.

7.4.2 Brief overview of economy-wide impact of COVID-19

A result of a Business Tracker Survey conducted by the Ghana Statistical Service (between May and June 2020) show that 35.7% of business establishments in Ghana closed down during lockdown, 46% of them reducing wages of over 25% of their staff. Merchandise imports and exports contracted respectively by 4.1% and 8.5%, combining with severe slow down in economic activity to cause the economy to contract by 10.6% in the second quarter ending

June 2020[48]. The Central Bank further stated, in the same report cited below, inflation spiked from 7.8% in the first quarter to 11.2% in the second, triggered in part by rising food price inflation (from 8.4% to 13.9% over the same period).

Whilst the rise in food prices was attributed partly to disruptions in the distribution system, the slump in the economy was caused by a range of factors including: steep fall in global demand for the country's major commodity exports (oil and cocoa); and the lockdown-related slowdown of activities in the formal sector as well as even more steeply in the informal sector, which dominates the national economy. Public finances were stretched as tax inflows dipped at a time there was intense pressure on government to implement COVID relief interventions.

In general, consumer demand weakened due to the above factors. Consequently, demand for alcoholic and non-alcoholic beverages fell, in part because of a slump experienced in the hospitality industry as social activities were restricted and tourist arrivals has fallen precipitously as shown in Figure 7.2 below. The breweries responded by cutting back production, an action which directly impacted on offtake of sorghum grain by the industrial brewery. Though the restrictions have been eased to a large extent, recovery has been rather slow, especially in the hospitality industry as the main air and land borders remain closed, hence limiting inflow of tourists. Furthermore, access to finance is problematic because though interest rates are reported by the Central Bank to have fallen marginally, the heightened uncertainty in the economy is stymieing formal lending, especially by the commercial banks.

Source: Bank of Ghana (July 2020).

7.4.3 Evidence of impact of COVID-19 on the sorghum value chain

This analysis is undertaken at different levels of the value chain: production, distribution and transformation. The season in focus is 2019/20 but using data for the 2018/19 season as the base. The analysis also considers some of the impacts beyond the 2018/19 season.

7.4.3.1 Impact on sorghum grain output

It is not anticipated that sorghum grain output in the 2019/20 season will be affected by COVID. This is because the harvest season was over just before its outbreak in the country during the first quarter of 2020. However, there is the possibility that the next season will be impacted. Delay in payments to SHF2 farmers is affecting inputs credit schemes, including the Revolving Fund supported by MOAP. This situation and reports suggesting delays in the

[48] *Source: Bank of Ghana Monetary Policy Committee Press Release, 27th July 2020.*

delivery of inputs, which is due to COVID controls, may dampen uptake of inputs. In addition, access to extension services is reported to have been affected by concerns over movements by field extension personnel. From consultations with some LMF and commercial farmers, it is anticipated that they will cutback planting.

The overall impact of these factors on total output is expected to be rather marginal in the 2020/21 season. We project that total output will not decline by more than 5-10% as production by SFH1 farmers will remain at the same level unless the weather and other biological risks affect output. The SHF1 farmers do not use much of the inputs and also have little or no access to extension advisory services.

The projected fall in output in the 2020/21 season is unlikely to weaken capacity to supply quality grains to industrial breweries as the volume they currently require is below total marketed output sourced from the SHF2 farmers. However, beyond that season, sustainability of production going into sub-chain 3 will depend on how quickly procurement by formal offtakers recovers.

It is likely that the impact of COVID-19 on grain output may be higher if incidence of the pandemic in rural communities is high. That is what occurred during the outbreak of Ebola in West Africa, as noted in Section 3.4.1. It is therefore important to strengthen rural health service delivery systems in order to address this risk if it should occur in future. This will also alleviate some of the existing health risks to which players in the chain are exposed.

7.4.3.2 Impact on sorghum grain offtake

The pandemic is unlikely to affect offtake of sorghum grain for pito brewing in the current season and beyond. This is principally because the controls imposed do not affect consumers. Figure 7.3 shows the typical "spot" where it is consumed. It is relatively low-risk in terms of spreading the virus because it is open space and it is feasible to enforce social distancing. Use of sorghum grain by micro-processors and microbreweries are also unlikely to be affected because these are sold in relatively small quantities.

Figure 7-2: Pito "drinking spot" in Wa in Ghana (June 2019)

However, offtake by the industrial brewery has been severely affected. Reports indicate that about 40% of the output grain contracted for the season could not be taken up. Farmers supplied to the aggregators, who deposited into warehouses designated by the company. Payment is however expected to be made only after the stocks are delivered to the brewery. For this reason, in our analysis we assume the volume involved has been sold but not utilised. Hence, the main actors whose operations are altered are the brewery and suppliers of related goods and services (e.g. packaging materials etc.).

The analysis indicated the reduction in grain utilisation by the brewery leads to a 17% decline in total value added in the value chain, as the value added contributed by grain transformers falls by 21%. Further to this, public finances will be impacted negatively as the contribution to taxes and levies from grain transformers declines by almost 29%.

The above analysis shows that though the shortfall in volume taken up by the industrial brewery is only 7,200 tonnes, which is less than 5% of the total grain marketed and 2.6% of total grain output, the fall in value added in the chain is quite sharp. This indicates a vulnerability, not only for SHF2 farmers but even more so for the emerging large-scale grain aggregators as they are dependent on the industrial brewery's purchases. This challenge can be mitigated by promoting a diversified range of formal offtakers of quality sorghum grain, an option demonstrated to be feasible in Section 7.3.2. There is, however, an urgent need to address liquidity problems created in farm households as a result of the COVID-related delay in payments for grain delivered this marketing season.

7.5 Conclusion

The results of analysis reported in Chapters 4 to 6 have shown that the sorghum value chain in Ghana does not only offer a means to manage food security with a resilient crop but can also be a significant vehicle for transforming lives in Northern Ghana. In this chapter some of the options for achieving the latter objective have been explored. First among these is scaling up support to smallholder farmers to enable them take up yield-enhancing inputs which are available to them at subsidised prices under the government's PFJ. This experience of the SHF2 farmers demonstrate that support in the form of inputs credit impacts directly on inputs uptake and significant increase in yield obtained by farmers. By enabling them acquire just about 20% of their of their inputs needs, the yields these farmers obtain can increase by over 30%. The yield boost can lead to substantial increase in farm household income, enabling smallholder farmers who rely solely on sorghum production to escape poverty – the evidence shows that they can obtain income which is above the national poverty line from cultivating only sorghum if they receive this support. The support will also ensure equity principally because it will make it possible for poor smallholder farmers (SHF1) to benefit from the inputs subsidies under PFJ, for which they, justifiably, should be the prime targets.

It is apparent from our analysis that there exists sufficient offtake capacity to sustain increase in sorghum grain output in the country. This is particularly so at the level of pito brewing. The market for pito has the potential to grow if consumption of the non-alcoholic type is scaled up. This will require packaging and marketing actions aimed at lowering existing religious barriers which currently discourage consumption of non-alcoholic pito despite its nutrition benefits. Pito brewing can become even more profitable, generate substantially higher household income, contribute more to value added in the chain and have far less deleterious environmental impacts if brewers adopt more energy-efficient combusting technology which is currently available in Ghana. Our estimates indicate that the significant incremental income generated by adopting of the technology will ensure that any capital investment required can be amortised over a relatively short period. The technology upgrade is such that it will not have adverse impact on inclusiveness in the value chain as pito brewing continues to be dominated by women.

The role of the industrial brewery in the sorghum grain market has driven growth in the sub-chain 3, making it possible to assure consistent delivery of quality grains existing and future investors in grain transformation (e.g. processors and other brewers). This is partly because of the modern aggregation system which has emerged in sub-chain 3. However, COVID-19 and its impact, as discussed above, has quite starkly shown the vulnerability of actors relying on its procurement, especially SHF2 farmers, commercial farmers and large-scale aggregators. Actions to diversify offtake capacity will, therefore, be critical in achieving rapid, inclusive and sustainable growth in the value chain, including fostering efficiency gains which reduce environmental impacts of activities in the chain.

8 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

8.1 Overview of sorghum value chain

The sorghum value chain in Ghana has been shown in this report to be not only resilient in terms of climate-related risks but also profitable at all levels in the chain; making a contribution to the national economy as well as making a net contribution to public finances and generating paid employment. There is evidence that it is socially and economically sustainable, whilst real possibilities exist for lowering the environmental effects at certain levels in the chain. Evidence generated in this study also point in the direction of potential "low-hanging" wins in driving sustainable productivity growth at the level of production of the crop and in catalyzing investments in downstream activities which can further sustain the overall transformation of the value chain. These issues, which have been discussed in this report, are summarized in this chapter along with some recommendations on taking the transformation agenda forward.

Sorghum is a highly resilient food crop, which contains no gluten-forming proteins, thus making it safe to be consumed by people suffering from coeliac disease, or those allergic and intolerant to wheat, rye and barley. It also contains varying quantities of essential minerals such as potassium, phosphorus and magnesium. In the US it is mainly used as a feed for livestock but in most developing countries, including Ghana, it consumed as food or brewed into traditional low-alcohol beer. It thrives mainly in the Northern Regions of Ghana, which are generally drier than the rest of the country, making its cultivation an important part of a climate-resilience strategy.

The population in Northern Ghana is predominantly rural and heavily dependent on agriculture for their livelihood. Incidence of poverty is high in the agriculture-dependent communities and official reports indicate that the majority of persons living below the poverty line in Ghana live in the Northern Regions[49]. Sorghum is the second most widely cultivated crop in Northern Ghana, hence its performance can directly impact on the wellbeing of the population. However, its growth performance between 2008 and 2017 was rather erratic, being generally out-performed by all other cereals subsectors cultivated in Northern Ghana.

Though it is considered a food security crop, domestic sorghum prices have consistently been higher than maize wholesale prices since 2008 as reported by SRID. In 2010 maize was about 25.4% cheaper than sorghum whilst in 2017 it was close to 35% cheaper. This may explain the growing relative importance of maize in the food systems in Northern Ghana. The country also appears to be a rather high-cost producer of sorghum. In 2017, when the wholesale price of sorghum was equivalent to about US$240 per tonne, global market prices ranged from US$100 to US$200 per tonne. In the Southern African markets the average price per tonne of sorghum during that year is reported to be over 30% lower at about US$160.

Improving cost-competitiveness will require a significant increase in farm productivity as well as sustained growth in demand for sorghum, in market segments which allow for bulk sales by producers and offer remunerative and predictable prices. According to the smallholder farmers consulted, it is these features which make the emerging sub-chain 3 attractive.

8.2 Economic contribution and sustainability of sorghum value chain

The sorghum value chain provides profitable opportunities from grain production through distribution and marketing to transformation into consumer products. This is shown in the financial analysis reported in Section 4.2 and includes grain production by the low-input, low-yield smallholder farmers (SHF1). The chain is an important source of income for the actors engaged in the chain.

The value chain in 2018 generated total value added estimated at GHS 1,016 million, which is equivalent to almost US$211.2 million or €188 million and represents almost 2.0% of the overall agricultural GDP in Ghana. Grain producers account for 17.5% of value added in the chain, double the contribution from players in the distribution chain such as rural collectors, aggregators, wholesalers and retailers), whose contribution is 8.5% of the total. The bulk of value added is generated by transformers, with the pito brewers accounting for 19.7% of total value added whilst industrial brewers, microbreweries and grain processors together generate 22.1% of total value added. The remaining 32.2% of value added generated in the chain is from suppliers of goods and services to the main chain actors.

[49] *Philip Alston (Special Rapporteur on Extreme Poverty and Human Rights) on his mission to Ghana, 9-18 April 2018.*

The chain is also a net contributor to public finances in Ghana, providing about GHS 159 million (i.e. $33 million or €29.4 million) per annum in the form of taxes and local council levies. This figure is net of the inputs subsidies under PFJ, which is estimated at GHS 6.7 million. The subsidies represent only 4% of the gross tax revenues from the value chain. It must be noted, however, that the poorest category of farmers, the SHF1, are not benefiting from the subsidy due to their inability to raise funds on their own to pay 50% of the cost of the inputs as required under PFJ.

Currently, only trace volumes of sorghum grain are reportedly exported by Ghana into regional markets. About $41.2 million (i.e. €36.7 million), is spent on imported intermediate goods and services within the chain. The use of sorghum grain as a local raw material in brewing by the industrial brewery is saving about $7.6 million (€6.6 million). The sorghum VC creates about 180,000 opportunities for self-employment, including smallholder farmers as well as those engaged in sorghum grain distribution (collectors, aggregators and retailers). There are also over 5,500 self-employed pito brewers, an industry which employs about 15,000 low-wage workers, almost all women, who also take advantage of the employment to accumulate start-up equity for their own pito brewing enterprises. There is evidence that new low-wage, temporary ("by-day") labour employment opportunities have emerged along with more permanent and better-remunerated jobs have been created as a result of commercial sorghum cultivation and grain aggregation.

The value chain is well-integrated into the local economy as shown by its estimated rate of integration of 78%. The domestic resource cost (DRC) ratio in the chain is also estimated at 0.35, which is well below unity (i.e. <1) and indicates that the value chain has a comparative advantage and is viable within the global economy. The nominal protection coefficient is 1.1, an indication that players in the chain currently enjoy a certain level of protection. The value chain is also highly inclusive as evidence generated through this study shows that most of the income generated in the chain (about 78.5%) accrues to small and micro-scale actors including smallholder farmers, small/micro-scale grain collectors and retailers as well as small-scale processors and pito brewers.

8.3 Social sustainability of the sorghum value chain

The value chain has the capacity to be socially sustainable. As a cash crop, the value chain offers opportunities for small-scale farming, small businesses and entrepreneurs. Engaging youth as SHF2 farmers would alleviate land tenure and inheritance impediments. However, security of growth of the emerging Sub-chain 3 is important in assuring long-term employment security for the rural workforce as a majority of them in the value chain are being employed on an informal, casual or temporary basis due to uncertainty regarding demand. This is especially the case if the commercial brewer scales down utilisation of sorghum in brewing. That will have significant implications for job and income security.

The sorghum value chain contributes to inclusive economic growth but is operating far below its potential. The Sub-chains 2 and 3 contribute to inclusive growth through the involvement of three groups of participants and beneficiaries: small scale producers who produce relatively small quantities on small plots of land (accounting for almost 95% of total production), the pito-brewers and a workforce that supports the system of production, trading and processing. Women in particular benefit from employment opportunities as they carry out most of the tasks associated with production and the traditional processing. Both, men and women gain a degree of financial independence from their involvement in the VC. Returns from small-scale production benefit the local economy and are invested in children's education, health care, housing, small businesses and in the farm. However, sorghum could contribute much more if the challenges identified were taken into account. These challenges are in the areas of: i) no effective smallholder farmer groups and power imbalances between VC-actors, ii) low farm labour wages and harsh working conditions for pito brewers, iii) land tenure system, iv) gender inequality (no access to land and credit and low decision power), v) availability and affordability of health care and investment in vocational training.

It is evident that increased productivity of sorghum can be socially, economically and environmentally sustainable for all VC actors. The sorghum smallholder farmers are responsible for producing an estimated 90% of Ghana's total sorghum production. As well as the direct benefits of sorghum sales accrued by smallholder farmers and their families, the VC also provides important opportunities for local employment at key points during production and processing (particularly at harvest time) and contributes to maintaining a dynamic local economy. While sorghum represents a source of income for many smallholder farmers and pito brewers, the sorghum sector in Ghana faces a number of challenges and disincentives that limit the VC from achieving its full potential in terms of social and economic benefits. Some of these issues are addressed in our recommendations.

8.4 Environmental sustainability of the sorghum value chain

The LCA analysis of sorghum products focused on four main stages: agricultural production; cleaning and sorting including transport from field to warehouse; transport to the brewing site; and malting, brewing and packaging. The environmental inventory was based on data collected during two field missions in Ghana where farmers and other stakeholders related to the agricultural sector, were interviewed. An endpoint assessment of the impacts in each damage category was carried out with the ReCiPe 2016 method.

For all the products, the main impacts are due to ecosystem quality and human health, while impacts on resource are very low in all products. The contribution analysis of the life cycle stages revealed that the main contribution derives from different stages: firewood extraction and combustion in *pito* brewing, cultivation of the grain and packaging materials used by industrial brewing.

In the *pito* brewing, 97% of the impacts in the human health domain is derived from the firewood extraction and combustion for the brewing process. Cultivation, alongside firewood extraction and combustion for brewing had a major contribution in ecosystem quality and resources depletion. Considering that the alternative scenario (reduction of firewood use) affects these impacts, there is a large room for improvement in the *pito* value chain. In particular, widespread adoption of the oven technologies seems to be feasible, since the technology is already available in Ghana and some *pito* brewers have already adopted it.

In sub-chain 2, cultivation has a major contribution to the overall impacts, in particular in terms of ecosystem quality (98% of the impacts derive from the cultivation phase). The main contribution in the other two areas of protection (resources and human health) is generated at the brewery, being energy –fossil fuel and electricity– the main contributor (83% and 45% in terms of resource and of human health, respectively). A large consumption of water at the brewery (15 L / L of beer) makes its contribution to the human health area almost as important as that of cultivation (13% and 15% respectively).

The alternative scenario for sub-chain 2, i.e. the introduction of the best scenario of sorghum farming (BSSF), affects mainly the ecosystem quality. Considering that the energy efficiency of a small-scale industry is often difficult to improve (the microbrewery has a production of only 20,000 litres / year), there is hardly space for improving this aspect. Water use at the brewery is high (15 L /L of beer), but it is in line with the typical water consumption of small-scale breweries.

In sub-chain 3, cultivation had a major contribution in the ecosystem quality (59%). The main contribution in the other two areas of protection (resources and human health) is linked to the processing stage, being glass packaging and energy –fossil fuel and electricity– the main contributors. In terms of resources damage, packaging and energy contributions are 55% and 32% respectively. In terms of human health, packaging and energy use contribute by 74% and 8% respectively. Since glass bottles production has such a large impact, in case a packaging reuse through a system of returnable containers is in place, impacts from glass bottles production can be largely ameliorated. According to the information gathered during the field missions, bottles reuse was in place until recently in Ghana through a deposit-refund system[50], but lately this virtuous system has been replaced by a retail system based on non-returnable containers.

For this sub-chain, under the alternative scenario (grain production by BSSF) it is assumed a more efficient crop management of SHF2, leading to an increase in yields, which can potentially improve land use and therefore ecosystem quality.

As it was previously discussed, the milling operation has negligible environmental impacts, therefore it can be concluded that for the milled grains there is no significant contribution of impacts from this operation; environmental impacts of milled grains can be assimilated to those of grains at farm gate.

This LCA study of sorghum-based products in Ghana provides an up-to-date reference regarding their environmental performance and allows for identifying margins of improvement for all three sub-chains. Regarding the processing phase, this is particularly true for sub-chains 1 and 2. Increasing sorghum yields of SHF2 would affect

[50] *Based on the collection of a monetary deposit on beverage containers at the point of sale to ensure that the packaging can be returned to the brewery, washed and refilled.*

the whole value chain by improving land use, which is one of the main issues of the sorghum value chain. In the case of sub-chain 1, the introduction of ovens for *pito* brewing can have very positive impacts both from human health and ecosystem quality perspectives. Indeed, it would contribute to the reduction of firewood consumption, of direct exposure of brewers to harmful open fire pollutants and to the reduction of forest degradation.

8.5 Transforming sorghum value chain: the feasible options explored

The sorghum value chain shows considerable potential for rapid and inclusive growth which is also socially, economically and environmentally sustainable. This has been demonstrated in various options explored in the preceding chapter and is summarized below. It includes spurring growth in sorghum grain output; fostering improvements in grain uptake; and promoting expansion in the emerging modern grain distribution system. The outcome of our analysis of these options as well as an examination of the impact of COVID-19 on the value chain are summarized below.

8.5.1 Boosting farmers productivity: ensures equity and can reduce rural poverty

Two options are explored with the aim of increasing volume of sorghum grain produced by smallholder farmers. The first involves scaling up inputs credit schemes which enable smallholder farmers to access subsidised inputs distributed under the PFJ. Currently, SHF1 farmers are unable to access such inputs though they are targeted. This is largely due to lack of finance. Access to inputs credit for only 20% of their estimated requirements will enable them increase average yield per hectare by about 30%, from about 0.65 tonnes to 0.85 tonnes per hectare. The increased level is still about 30% below current official estimates of the national average yield of sorghum, which is about 1.2 tonnes per hectare.

The second intervention is to support smallholder farmers to take up simple and available sun drying technology involving the use of tarpaulins. This is already being done in the case of some SHF2 farmers who are assisted by large-scale sorghum grain aggregators. It is anticipated that such an intervention can reduce postharvest losses in the sorghum subsector by about 35%, which sets the chain on the right trajectory to meet the governments commitment under the Malabo Declaration to reduce postharvest losses by 50% by 2025. That reduction implies savings of 11,945 tonnes of grain with market value of GHS 12.9 million (i.e. US $2.69 million or €2.38 million).

The combined effects of increasing yields obtained by smallholder farmers and lower postharvest losses include very tangible economic, social and environmental benefits. For instance, it has a positive impact on household food security as sorghum grain available for consumption is projected rise, on the average, by over 40%, from about 8.5 bags to 12 bags (or 0.6 tonnes) per farm household. Average sorghum-based income which SHF1 farmers obtain almost doubles to an estimated at GHS 412.50 (equivalent to $86 or €76), per annum per farmer – assuming the SHF1 farmers continue to allocate only 30% of cultivated land to sorghum. However, the projected annual farm income if they commit 100% of their cultivated land to sorghum under proposed scenario will be about GHS 1375 ($285 or €255), which ***is above the national poverty line*** (estimated at GHS 1,315 in 2017) even if only slightly.

Farm income for SHF2 farmers from sorghum production is also projected to rise by an estimated 30% to about GHS 800 (i.e. $165 or €150) per annum at current levels of allocation of cultivated land to sorghum. We project that if they commit 100% of their area planted to sorghum with the extra support proposed, they can obtain about GHS 2,000 ($415 or €370) per annum. The anticipated social benefits from increased household income, which include increased investment in child education, are reported in Chapter 5. In addition, it is expected that yield gains will produce long-term environmental effects as noted by Burney et al. (2010).

To sustain productivity growth at the farmer-level, there is also need to invest in assuring adequate supply of viable seed. This will require public investment in addressing human capacity and funding constraints facing SARI. It is also important that SARI focuses on both the white and red sorghum varieties. Regulatory enforcement of seed certification and licensing controls should also be robustly enforced to avoid compromises which lead to sale of non-viable.

8.5.2 Growth in formal offtake needed to sustain increased output

Improved offtake capacity is essential in sustaining output and productivity growth in the sorghum value chain. The options explored include the following:

- Promoting energy-efficiency in pito brewing and marketing non-alcoholic pito by lowering existing barriers to its consumption. To achieve the former, pito brewers need to be encouraged to adopt more energy-efficient stoves, which are available and relatively low-cost, with potential for cost-recovery within one and two years.
- Encouraging uptake sorghum in other breweries, including for example the Accra Brewery Limited (ABL) as well as by microbreweries. The latter will promoting the emergent microbreweries through access to low-cost start-up capital as it is a new industry;
- Fostering sorghum grain processing by enabling the micro-scale processors to scale up their operations through schemes such as incubation hubs which ease start-up finance constraints and also help them to overcome relevant licensing and regulatory requirements.
- Supporting upscaling of the modern grain aggregation and distribution system which is emerging in sub-chain 3.

8.5.3 Impact of potential interventions explored

In Section 8.5.1 we reported the projected increase in household income for smallholder farmers as a result of increased yield and output. Total value added generated in the value chain is also projected to rise by almost 65% to about GHS 1.67 billion (equivalent to just over US $345 million or €310 million). Assuming the same base as in 2018, this figure will represent a contribution to agricultural sector GDP of about 3%. Wage earnings attributable to the sorghum value chain rises by over 40% whilst its contribution to public finance grows by more than 30%. Income accruing to all actors in the chain increases by almost 60% but the chain remains highly inclusive and socially sustainable as close to 80% of the income accrues to small/medium-scale actors such as smallholder famers, micro, small and medium-scale aggregators as well as pito brewers, who are predominantly women.

8.5.4 Impact of COVID-19

Though incidence of the pandemic has been extremely low in the sorghum producing regions, it has had significant impact on the value chain. This impact is evident in the 2019/20 season and is likely to continue into subsequent seasons. Slump in demand for their products compelled the industrial brewer to cutback production, resulting a reduction of sorghum grain utilisation by about 40%. The grains contracted for delivery during the 2019 harvest was required to be warehoused, with the brewery committed to making payment. However, payment has been delayed until the stocks are delivered to the brewery site.

The delay in payment has created liquidity problems for aggregators and farmers, a situation likely to impact negatively on uptake of farm inputs, especially where SHF2 farmers have been unable to repay inputs credit taken during the 2019 planting season. If this remains unresolved, the negative impact on grain production is expected to last beyond the 2019/20 season. Our analysis shows that the immediate impact of the reduction in grain utilisation by the brewery is a 17% decline in total value added in the value chain. Furthermore, public finances will be impacted negatively as the contribution to taxes and levies from grain transformers projected to fall by almost 29%.

8.6 Concluding note

The sorghum value chain in Ghana evidently offers a means to manage food security as it is a resilient crop. It has also been demonstrated to provide income to all actors including smallholder farmers, aggregators and grain transformers, including especially pito brewers, who are predominantly women. The VC provides important opportunities for local employment at key points during production and processing (particularly at harvest time). It contributes public finances and to national economic growth, in a manner which is inclusive. The chain is socially and environmentally sustainable. However, as noted by all the three experts, its performance can be transformed with very tangible benefits if actions are implemented to boost smallholder farmers output and productivity as well as scale offtake capacity, including promoting greater efficiency in pito brewing.

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ANNEXES/APPENDICES

APPENDIX I – SOCIAL PROFILE

Sorghum		Country:		*Ghana*	Date Last Modification:	4-11-2019
Dimension	Count	Score level	**Trend**	**Major risks and possible negative consequences**	**Mitigating measures**	**Comments**
1. WORKING CONDITIONS						
1.1 Respect of labour rights	2.40	Moderate/Low	↑	Rural (wage) farm labour is not monitored by the Ministry of Labour. This can be a risk for wage labourers and we noticed cases where they are paid below the minimum wage. Farm wage labour is replaceable and often not contracted. MoFA and Min. of Labour should join forces,	Requires strong efforts not from the government on monitoring and enforcements of labour laws and regulations. Labour associations and worker representation could improve transparency.	
1.2 Child Labour	3.00	Substantial	↑	None identfied	Not applicable	
1.3 Job safety	2.00	Moderate/Low	↑	Work environment of pito brewers is hazardeous. Farm wage labourers are vulnerable in the field (e.g. snake bites).	Stronger awareness raising among farm labourers and preventive measuments (e.g. always first aid kit in the field, transportation means avaialble in case of emergency). For the pito brewing process the more advanced systems (see photo report) decreases the harsh and dangerous work environment.	

1.4 Attractiveness	2.50	Substantial	↑	There is global trend of urbanisation and youth migrating to urban areas and non-agricultural sectors. But sorghum, especially the new variety is attractive compared to other agricultural sectors in Ghana. Business opportunitise and innovation is limited as a consequence of low vocational training and no acces to credit.	Investment in vocational training at all stages in the chain; possibilities for access to credit.	
Average	2.48	Moderate/Low	↑			
2. LAND & WATER RIGHTS						
2.1 Adherence to VGGT	1.00	Not at all	↑	Land transfer from small to medium and large producers could threaten the position of smallholders. Smallholders might be willing to sell their land at a very low price leaving them with noting in the lon run. Smallholder farmers can hardly expand their land as they need permissio n from the chief and they have no resources for additional agri-inputs.	Awareness raising among smallholders to prevetn them from selling their land. Enable smallholder to increase their acreage with sorghum. Also lobbying to clarify vulnerable position of smallholders in negotiating the price.	
2.2 Transparency, participation and consultation	1.50	Moderate/Low	↑	Not applicable	Not applicable	
2.3 Equity,compensation and justice	2.00	Moderate/Low	↑	Climate change, natural disasters and water scarcity are bigger challenges and insufficient coping measures seem to be in place. This threatens the sector in its entirety, assurance of expert markets and the position of smallholders and workers.	Innovate in the sector to manage climate change; at the level of producers, but also at level of public goods. Requires strong position public sector or collaboration in the sector.	
Average	1.50	Moderate/Low	↑			
3. GENDER EQUALITY						

3.1 Economic activities	2.00	Moderate/Low	↑	Women participation in certain segments of the chain, production, (post) harvest, pito brewing and trading of the traditional variety (the red one). For the commercial variety for the GBBR women participation is low in the chain and their possibillities are limited.	Higher participation of women in th VC may be promoted, but would require cultural shift as well; Facilitate access to credit and training for women.	
3.2 Access to resources and services	1.00	Not at all	↑	Access to land and land titles and land cultivation are lower for women which also results in limited access to credit.	Overall increase in property rights will help as well as access to credit through associations (if established).	
3.3 Decision making	1.60	Moderate/Low	↑	Women have little decision making power in terms of production decisions, which may further exclude them from capacity development and overall growth.	Promoting participation of women in technical capacity building. But also gain more insight into the desire of women to participate in the production process aside from domestic work, care for family and other income generating activities.	
3.4 Leadership and empowerment	1.75	Moderate/Low	↑	Limited involvement of women in leadership positions may limit increase in gender equality.	Higher participation of women in theVC may be promoted, but would require cultural shift as well	
3.5 Hardship and division of labour	1.50	Moderate/Low	↑	Overall workload for women is higher;	Very challenging, would require cultural shift, but also better services for women (e.g. day care)	
Average	1.57	Moderate/Low	↑			
4. FOOD AND NUTRITION SECURITY						
4.1 Availability of food	2.50	Substantial	↑	Not a key challenge but could be a risk if there is large scale substitution of food crops with the white variety of sorghum.	If smallholders are able to produce larger areas and are provided with credit to make agricultural inputs affordable, this risk is mitigated.	

4.2 Accessibility of food	2.00	Moderate/Low	↑	Period food shortages: June, July and August on average.	Increasing production, reducing cost increasing resilience, access to credit at the time of land preparation. Timely payment of produce sold.	
4.3 Utilisation and nutritional adequacy	2.00	Moderate/Low	↑	There is no clear indication of changing nutritional practices, especially not in the rural areas in the three northern states. Low awareness on nutrition risking health, low availability of nutritious products in the northern states.	Education is needed. Probably, outside the scope of the VC. Increase and facilitate availability of more nutitious food items in the northern regions (vegetables and fruit).Facilitate promotion of non-fermented, non alcohol pito for children.	
4.4 Stability	2.00	Moderate/Low	↑	Only a risk if there is high substitution of food crops with the cash crop sorghum used for professional and large scale brewing (GBBR)	Proper measures to manage climate change and diversify income portfolio and faciltate smallholders to increase acreage used for food and cash crops. (see above).	
Average	2.13	Moderate/Low	↑			
5. SOCIAL CAPITAL						
5.1 Strength of producer organisations	1.25	Not at all	↑	Risks related to accountable leadership, limited negotiation capacity and farmer representation. Collaboration and cooperation is no intrinsic motivation of producers but a vehicle to get support.	Capacity building of groups, cooperatives and associations.	
5.2 Information and confidence	2.00	Moderate/Low	↑	Mistrust in various links in the chain.	Better organization of the sector and stronger involvement of the public sector. Establish a sector platform / lobby. Monitor monopoly position of GBBR.	

5.3 Social involvement	2.33	Moderate/Low	↑	No potential risk, except for potential reduction of public involvement because of it.	Not applicable	
Average	1.86	Moderate/Low	↑			
6. LIVING CONDITIONS						
6.1 Health services	2.00	Moderate/Low	↑	Accessibility and affordability still a challenge in the rural areas. Affordability a challenge for majority of chain actors. Unstable incomes, remoteness, no availability of medical care adn basic services in the remote rural areas, alck of savings and health insurance are risks.	Improved production and efficiency, on-time payment; payment via bank accounts, discount or facilities for farm wage labourers. Improving health insurance system. Improve stocking of medical health care posts in the villages. Monitoring and control of the CHPS.	
6.2 Housing	2.00	Moderate/Low	↑	Access to water is generally poor in the rural areas and poses risk	Through improved income, but also public efforts	
6.3 Education and training	2.33	Moderate/Low	↑	Secondary education and vocational training remains a big challenge. School fees, clothing and materials still a challenge for the poorest of the poor. Primary education not always accessible in the rural areas. Both may prevent livelihoods from improving and the sector from becoming more efficient and inclusive.	Better organization of the sector and stronger involvement of the public sector may help	

Appendix II: Life cycle inventory of sorghum cultivation in three farm types including field emissions. Units are referred to 1 ha and to 1 ton of grain production (12% moisture content)

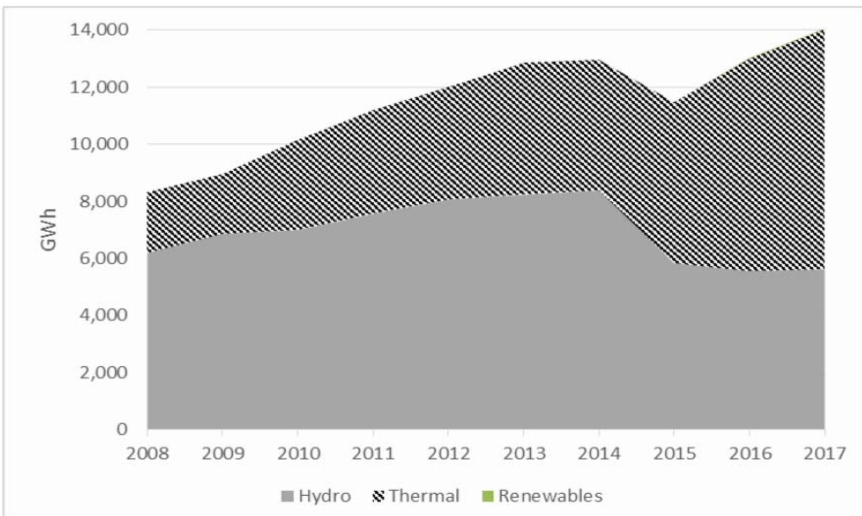
		SHF1 - Small holder farmers (NO INPUTS)	**SHF1** - Small holder farmers (20% INPUTS)	**LMF** - Lead-medium farmers (100% INPUTS)	**CF** - Commercial farmers (100% INPUTS, mech. sowing and harrowing)
Contribution to total sorghum grain output (%):		*62.3*	*36.1*	*1.2*	*0.4*
		per 1 ha			
INPUTS	unit	SHF1	SHF2	LMF	CF
Land occupation	m2/ha	10,000	10,000	10,000	10,000
Seeds, improved (purchased)	kg/ha	-	-	12	12
Seeds (grains used as propagation material)	kg/ha	30	30	-	-
Ploughing	MJ/ha	446	446	446	893
Harrowing	MJ/ha	-	-	-	276
Sowing (CF: 50% mechanical)	MJ/ha	-	-	-	69
Mechanical threshing (80% for CF, 50% LMF)	MJ/ha	-	-	43	96
NPK compound (15-15-15)	kg/ha	0	50	250	250
Ammonium sulfate	kg/ha	0	25	125	125
Herbicide, CF and LF : @ required levels, SHF1: 20%	L/ha	-	0.49	2.47	2.47
Water for herbicide application	L/ha	-	49	247	247
PE bags for grain packaging	g/ha	72	94	198	275
Transport of inputs for cultivation	tkm	0.00	4.5	23.2	23.2
OUTPUTS					
Sorghum grains	**kg/ha**	**650**	**850**	**1,800**	**2,500**
PE bags inert waste treatment	g/ha	72	94	198	275
Direct N2O emissions	kg/ha	0	0.20	1.0	1.0
Indirect N2O emissions	kg/ha	0	0.01	0.05	0.05
N2O emissions from crop residues	kg/ha	0.19	0.24	0.34	0.43
NH3 emissions	kg/ha	0.0	0.46	2.32	2.32
Emissions of PO4 from leaching and run-off	kg/ha	0.0	0.24	0.26	0.26
Emissions of P from soil erosion	kg/ha	10.7	10.7	10.7	10.7
		per 1 ton of grains at farm gate (at 12% harvest moisture)			
INPUTS	unit	SHF1	SHF2	LMF	CF
Land occupation	m2/ton	15,384.62	11,764.71	5,555.56	4,000.00
Seeds, improved (purchased)	kg/ton	-	-	6.67	4.80
Seeds (grains used as propagation material)	kg/ton	34.89	34.89	-	-
Ploughing	MJ/ton	686.77	525.18	248.00	357.12
Harrowing	MJ/ton	-	-	-	110.31
Sowing (CF: 50% mechanical)	MJ/ton	-	-	-	27.58
Mechanical threshing (80% for CF, 50% LMF)	MJ/ton	-	-	-	38.39
NPK compound (15-15-15)	kg/ton	-	58.83	138.78	99.92
Ammonium sulfate	Kg/ton	-	29.42	69.39	49.96
Herbicide, CF and LF : @ required levels, SHF1: 20%	L/ton	-	0.58	1.37	0.99
Water for herbicide application	L/ton	-	58.14	137.28	98.84
PE bags for grain packaging	g/ton	110	110	110	110
Transport of inputs for cultivation	tkm	-	5.29	12.89	9.28
OUTPUTS					
Sorghum grains	**ton**	**1**	**1**	**1**	**1**
PE bags inert waste treatment	g/ton	110	110	110	110
Direct N2O emissions	kg/ton	0	2.35E-01	5.56E-01	4.00E-01
Indirect N2O emissions	kg/ton	0	1.21E-02	2.86E-02	2.06E-02
N2O emissions from crop residues	kg/ton	2.91E-01	2.85E-01	1.89E-01	1.73E-01
NH3 emissions	kg/ton	0	5.46E-01	1.3	0.9
Emissions of PO4 from leaching and run-off	kg/ton	0	2.81E-01	1.42E-01	1.02E-01
Emissions of P from soil erosion	kg/ton	16.5	12.6	5.9	4.3

APPENDIX III: ENERGY INPUTS FOR THREE SUB-CHAINS

Energy intensity and energy sources differ largely according to the sub-chain. In the *pito* sub-chain, since brewing requires high temperatures for mashing and boiling during several hours, firewood is used in large quantities. In the remaining chains, fossil fuels and electricity are used for the brewing process. A description of these energy sources follows.

Electricity production

Within this study, the production of electricity used in the value chain was modelled and used in replacement of the process available from the Ecoinvent database (*Electricity, high voltage {GH}| market for electricity, high voltage | Cut-off*) which was last updated in 2014. In recent years there has been a drastic reduction in the energy produced by the hydroelectric power and an increase in thermal energy in Ghana (Figure A.1)[51]. For this reason it was deemed necessary to update the process with the most recent data available, reported in the National Energy Statistics 2018 (Energy Commission, 2018) (Table A.1).



NB: Renewables is not showing because it is negligible

Figure A.1: recent trend in grid electricity generation.

Table A.1: Installed grid electricity generation capacity in Ghana in 2017

	Installed	Dependable	Installed	Dependable
	MW	MW	%	%
Hydro	1,580	1,380	36	35
Thermal	2,796	2,568	64	65
Renewables	23	18	1	0
Total	4,399	3,966	100	100

Thermal energy had a share of 60% from natural gas and of 5% from light oil. The transformation from high voltage to low voltage electricity and the distribution losses in the grid cause an overall loss of 22.4%[52], so that 1.224 kWh of high voltage electricity are necessary to obtain 1 kWh of low voltage electricity.

Firewood extraction and its impact on land use change

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[51] *Energy Commission of Ghana, 2018. National Energy Statistics 2008 – 2017. Strategic Planning and Policy Directorate.*

[52] *https://www.indexmundi.com/facts/ghana/indicator/EG.ELC.LOSS.ZS*

Fuelwood is one of the main energy sources in Ghana, being biomass the 41%[53] of total primary energy supply at national level. Firewood and charcoal production is concentrated in the transition zones between the forest and the savannah woodlands. Most of the wood is originated from savannah trees, which are felled for fuelwood production, and also from logging residues. It has been estimated that 91% of the total round wood production in Ghana is used as firewood and for charcoal. The remaining (9%) is used as industrial round wood.

Deforestation and forest degradation are important environmental issues in Ghana, linked both to fuelwood production and to expansion of agricultural lands. Firewood is a fundamental energy source in the sorghum value chain, in particular for sub-chain 1 which is the largest single offtaker of sorghum grains (43% of total sorghum grain production). Indeed, P*ito* brewing depends exclusively on this source of energy, used for the most energy intensive phases of brewing, i. e. mashing and mash boiling.

The process of firewood production and use simulated within this study includes the operation of tree cutting and felling with the use of a chainsaw feed by petrol and the transport of wood to the brewing site, at an average distance of 50 km. It was estimated that the wood is cut in woody savannah, close to villages or in the secondary or degraded forest and not in the primary forest, as this activity is illegal in Ghana and many areas of primary forest are protected reserves.

We considered that only the 50% of the woody biomass of one hectare of woody savannah was extracted, since it emerged from interviews that large trees and trees with an economic value (shea tree) are not felled. This hypothesis is supported by the fact that agricultural plots in Northern Ghana usually is scattered with trees, so that agricultural lands have similar characteristics of an agroforestry system.

The land use change triggered by firewood demand was modelled including in the inputs two land transformation flows, included in the ReCiPe 2016 method:

- Transformation, from forest, secondary (non-use)
- Transformation, to shrub land, sclerophyllous

The flow "Transformation, to shrub land, sclerophyllous" does not correspond exactly to a field with trees, but it is the closest land use change flow that was available in the ReCiPe 2016 method.

The land area subjected to land use change was calculated considering that half of one hectare undergoes land use change (5,000 m^2) and that in that area there is a production of wood (fresh matter) equal to 87.6 t. Dividing the area by the amount of wood, the area necessary for 1 kg of wet wood is obtained (0.057 m^2 kg^{-1}).

For the accounting of carbon loss due to land use change, reference was made to the Net Primary Production (NPP) of the Woody Savannah. Measured data on the carbon stock of Woody Savannah in Ghana are from a recent research[54] published with the collaboration of researcher of the Forestry Research Institute of Ghana, Council for Scientific and Industrial Research, Kumasi (FORIG-CSIR). A monitoring campaign was carried out in four different forest types in Ghana to measure forest biomass, productivity and carbon cycling along a rainfall gradient with the eddy co-variance approach. The study was carried out to monitor carbon fluxes with an eddy covariance tower and to obtain a Net Primary Production (NPP) dataset from lowland African tropical forests, as part of the Global Ecosystems Monitoring network[55]. The study was carried out in four vegetation types with low or no logging impact at 1 ha scale; evergreen forest (EF), semi-deciduous forest (SDF), dry forest (DF) and woody savanna (WS), while unfortunately a forest-savanna transition type was not reported. The carbon stock of these four different forest types are reported in Figure A.2, considering the carbon stock in all the components of the aboveground and belowground biomass and in soil.

[53] *Energy Commission of Ghana, 2018. National Energy Statistics 2008 – 2017. Strategic Planning and Policy Directorate.*

[54] Moore, S, Adu-Bredu, S, Duah-Gyamfi, A, et al. Forest biomass, productivity and carbon cycling along a rainfall gradient in West Africa. *Glob Change Biol*. 2018; 24: e496– e510. https://doi.org/10.1111/gcb.13907

[55] *GEM: gem.tropicalforests.ox.ac.uk*

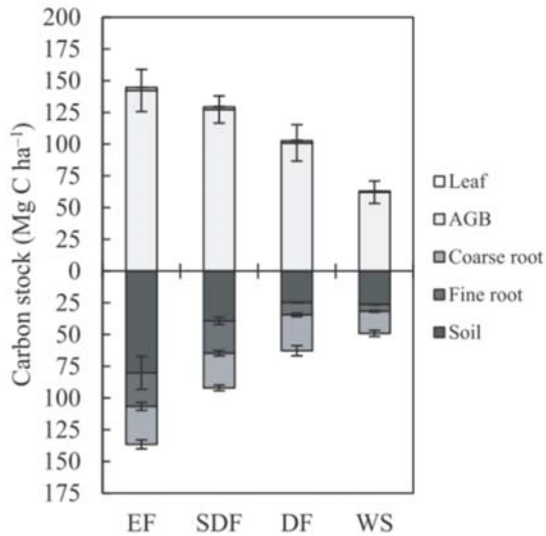

Figure A.2: Mean aboveground biomass, belowground biomass (fine and coarse root carbon stock) and soil carbon stocks (0 – 30 cm depth) of the four vegetation types (EF – evergreen forest, SDF – semi-deciduous forest, DF – dry forest, WS – woody savannah) along the rainfall gradient (modified from Moore et al, 2018).

As explained above, it has been assumed that there is a partial removal (50%) of trees from a woody savannah forest, thus we considered a land use transformation from a secondary forest to an arable land with trees, since some trees remain in the harvested land. We assumed that the carbon stock lost during forest cutting corresponds to the aboveground biomass and in soil, while it was assumed that the coarse and fine roots remain in the soil, since eradication is not carried out. The degradation of root biomass in soil is not included in the carbon lost since it would lead to much uncertainty to estimate the amount of carbon that will be oxidized to CO_2 and the amount that will be humified to organic carbon. According to the value reported in literature about the mean value of organic carbon in agricultural soil in the Transitional Zone and Woody Savannah (from 4 – 25 t C ha^{-1}: on average 14.5 t C ha^{-1})[56][57] and comparing with the value measured in the woody savannah (25 t C ha^{-1}) it is possible to say that half of the soil carbon stock is lost in the land use change.

An average content of carbon in dry woody biomass of 50% was considered along with an average moisture of wood equal to 46%. The carbon loss, both from the biomass and from the soil, calculated for 1 kg of firewood is reported in Table A.2.

Table A.2: Estimate of carbon loss for firewood extraction, including land use change.

Variable	Equation	Unit	Value	Note
Aboveground biomass (AGB)	A	Mg C ha^{-1}	60	Includes carbon in stem and branches
Soil carbon stock loss	B	Mg C ha^{-1}	12.5	Includes carbon in soil organic matter
100% loss of C stock	C = A + B	Mg C ha^{-1}	72.5	100% of the carbon of 1 ha is cut. It includes aboveground biomass carbon + soil carbon
50% loss of C stock	D = C / 2	Mg C ha^{-1}	36.2	50% of carbon of 1 ha is cut. It includes aboveground biomass carbon + soil carbon
Dry woody biomass	E = A / 2	Mg C ha^{-1}	30	50% of the carbon in AGB of 1 ha is harvested

[56] Bessah, E., Bala, A., Agodzo, S. K., & Okhimamhe, A. A. (2016). Dynamics of soil organic carbon stocks in the Guinea savanna and transition agro-ecology under different land-use systems in Ghana. Cogent Geoscience, 2(1), 1140319.
[57] Boakye-Danquah, J., Antwi, E. K., Saito, O., Abekoe, M. K., & Takeuchi, K. (2014). Impact of farm management practices and agricultural land use on soil organic carbon storage potential in the savannah ecological zone of Northern Ghana.

Dry woody biomass	F = E x 2	Mg ha^{-1}	60	From carbon to dry wood. It is considered a carbon content in biomass equal to 50%
Fresh woody biomass (46% moisture)	G = F + F • 0.46	Mg ha^{-1}	87.6	From dry wood to wet wood. It is considered a moisture in wet wood equal to 46%
Carbon loss per kg of wood	H = (D / G) x 1000	kg C loss kg^{-1} wood	0.414	kg of C loss in 1 ha divided by the quantity of wood obtained from 1 ha.

Summarizing, the calculated carbon loss attributed to firewood includes the carbon contained in wood plus the carbon loss from soil due to land use transformation as shown in Table A.3.

Table A.3: Carbon losses and CO_2 emissions of 1 kg of wood due to land use change and wood combustion.

Source	**kg C kg^{-1} wood**	**kg CO_2 kg^{-1} wood**
Land use change	0.071	0.262
Wood combustion	0.342	1.256
Total emissions	0.414	1.517

The emissions related to combustion of wood, other than CO_2, have been calculated starting from the emissions factor of IPCC 2006 guideline for CH_4, N_2O (EF for woody savannah, tab 2.5 vol. 4, Chapter 2) and from the EMEP-EEA guideline[58] for CO, NO_2, NMVOC, SO_x and particulates (EF, Fuel, Wood, technology: Open Fireplaces).

The LCI of firewood cutting and combustion is reported in Table A.4.

Table A.4: Life cycle inventory of firewood production and combustion. FU: 1 kg of firewood.

INPUTS	**Unit**	**value**	**Sources of data**
Wood, feedstock	kg	1	Primary data
Chainsaw use, hand felling	hr	0.0000986	Estimated from literature
Transport from the forest to brewing site (lorry 22 t euro 0-4)	tkm	0.05	Average distance of 50 km was estimated
Transformation, from forest, secondary (non-use)	m2	0.057	Calculated considering the productivity of woody savannah
Transformation, to shrub land, sclerophyllous	m2	0.057	Calculated considering the productivity of woody savannah
OUTPUTS	**Unit**	**value**	
Firewood, at wood market	kg	1	
Emission of CO_2 due to land use change	kg	0.262	Estimated using data from Moore et al, 2018
Emission of CO_2 due to wood combustion	kg	1.256	Estimated using IPCC 2006 default values
Emission of CH_4 due to wood combustion	g	1.24	Estimated using IPCC 2006 default values
Emission of N_2O due to wood combustion	g	0.113	Estimated using IPCC 2006 default values

[58] *European Environment Agency, 2019. EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019. Technical Guidance to Prepare National Emission Inventories. EEA Technical report No 13/2019. Publications Office of the European Union, Luxembourg. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019*

Emission of CO due to wood combustion	g	35.1	Estimated using emission factor from EMEP-EEA guideline
Emission of NO_2 due to wood combustion	g	0.678	Estimated using emission factor from EMEP-EEA guideline
NMVOC due to wood combustion	g	7.94	Estimated using emission factor from EMEP-EEA guideline
Emission of SOx due to wood combustion	g	0.146	Estimated using emission factor from EMEP-EEA guideline
Particulates, <10um due to wood combustion	g	11.1	Estimated using emission factor from EMEP-EEA guideline

APPENDIX IV: LIFE CYCLE INVENTORY OF THE NON-AGRICULTURAL UPSTREAM PHASES AND CORE PHASE. FU: 1 L OF PITO / 1 L OF BEER

Phase		unit	FU: *pito* / beer = *1 L*							
			sub-chain 1	source	sub-chain 2	source	sub-chain 3 (70% sorghum grains, 30% barley malt)	source	sub-chain 3 (100% barley malt)	source
Upstream: grains cleaning and storage at warehouse	**INPUTS**									
	Unsorted sorghum grains	kg	0.322	warehouse	0.273	warehouse	0.106	warehouse	-	-
	Electricity	Wh	-		-		0.151		-	-
	PE bags	g	0.044		0.037		0.014		-	-
	Road transport (fields to warehouse)	kgkm	19.313	60 km	16.377	60 km	6.362	60 km	-	-
	OUTPUTS									
	sorghum grains	kg	0.313	warehouse	0.265	warehouse	0.103	warehouse	-	-
	PE bags	g	0.044		0.037		0.014		-	-
	Residues from sorghum grain cleaning	kg	0.009		0.008		0.003		-	-
Upstream: malting	**INPUTS**									
	Sorghum grains	kg	0.3125	P maltster/brewer	0.27	MB brewer	-	-	-	-
	Water	kg	1.3		1.00		0.074		0.246	
	Barley, malting quality, national avg., farm gate/FR S	kg	-	-	-	-	0.0538	Kloverpris, 2009	0.179	Kloverpris, 2009
	Electricity	Wh	-	-	20.5	MB brewer	3.2		10.5	
	Natural gas	Nm3	-	-	-	-	0.002		0.007	
	Diesel fuel	kg	-	-	0.012	MB brewer	-	-	-	-
	Road transport (warehouse to malthouse)	kgkm	93.8	300 km	189	700 km	-		-	
	Road transport (barley, field – malthouse, in EU)	kgkm	-	-	-	-	10.76	200 km	35.88	200 km
	OUTPUTS									
	Malted sorghum	kg	0.25	P malstster/brewer	0.2	MB brewer	-	-	-	-
	Malted barley for Breweries, GH	kg	-	-	-	-	0.0441	Kloverpris, 2009	0.147	Kloverpris, 2009
	Sharps and sprouts from barley malting	kg	0.0625	P malstster/brewer	0.07	MB brewer	0.002		0.01	
	Wastewater	kg	1.085	MB brewer	0.85	MB brewer	0.063	Steffen, 1989	0.21	Steffen, 1989
	COD, Chemical Oxygen Demand	mg	3,255	Steffen, 1989	2,550	Stefen, 1989	31.5		104.6	

Note: values were adapted from the cited authors, downscaling to 1 L values provided in different FU.

Note: transport distances are assumed as typical distances (from production areas to processing sites)

APPENDIX IV-CONTINUED: LIFE CYCLE INVENTORY OF THE NON-AGRICULTURAL UPSTREAM PHASES AND CORE PHASE. FU: 1 L OF PITO / 1 L OF BEER

phase		unit	FU: *pito* / beer = *1 L*							
			sub-chain 1	source	sub-chain 2	source	sub-ch 3 (70% sorghum grains, 30% barley malt)	source	sub-chain 3 (100% barley malt)	source
Upstream: milling of sorghum malt	**INPUTS**									
	Malted sorghum	kg	0.25	P brewer	0.2	MB brewer	-	-	-	-
	Electricity	Wh	1.38	MB brewer	1.1	MB brewer	-	-	-	-
	Steel, hammer consumption	g	2.06E-03	Kloverpris, 2009	2.06E-03	Kloverpris, 2009	-	-	-	-
	OUTPUT									
	Grits, from sorghum malt	kg	0.25	P brewer	0.2	MB brewer	-	-	-	-
Upstream: milling of barley malt	**INPUTS**									
	Malted barley	kg	-	-	-	-	0.0441	Kloverpris, 2009	0.147	Kloverpris, 2009
	Electricity	Wh	-	-	-	-	0.3		1.40	
	Steel, hammer consumption	g	-	-	-	-	6.18E-04		2.06E-03	
	OUTPUT									
	Grits, from malted barley	kg	-	-	-	-	0.0441	Kloverpris, 2009	0.147	Kloverpris, 2009
Upstream: milling of sorghum grains	**INPUTS**									
	Sorghum grains	kg	-	-	-	-	0.103	Kloverpris, 2009	-	-
	Electricity	Wh	-	-	-	-	1.1		-	-
	Steel, hammer consumption	g	-	-	-	-	6.18E-04		2.06E-03	Kloverpris, 2009
	OUTPUT									
	Grits, from sorghum grains	kg	-	-	-	-	0.103	Kloverpris, 2009	-	-

Note: values were adapted from the cited authors, downscaling to 1 L values provided in different FU.
Note: transport distances are assumed as typical distances (from production areas to processing sites)

Appendix IV-continued: Life cycle inventory of the non-agricultural upstream phases and core phase. FU: 1 L of pito / 1 L of beer

Phase		unit	FU: *pito* / beer = *1 L*							
			sub-chain 1	source	sub-chain 2	source	sub-ch 3 (70% sorghum grains, 30% barley malt)	source	sub-chain 3 (100% barley malt)	source
Core: brewing (including pasteurization, packaging and wastewater treatment where applicable)	**INPUTS**									
	Road transport (barley malt, EU)	kgkm	-	-	-	-	8.82	200 km	29	200 km
	Sea transport (ship, barley malt, EU to GH)	kgkm	-	-	-	-	353	7,130 km [sea-distances.org]	1049	7,130 km [sea-distances.org]
	Road transport (barley malt, GH)	kgkm	-	-	-	-	13.2	300 km	44.1	300 km
	Road transport (sorghum grains, GH)	kgkm	93.8	300 km	198	700 km	41.2	400 km	-	400 km
	Grits, from sorghum malt, GH	kg	0.25	P brewer	0.2	MB brewer	-	-	-	-
	Grits, from sorghum grains, GH	kg	-	-	-	-	0.103	Kloverpris, 2009	-	-
	Grits, from malted barley, GH	kg	-	-	-	-	0.044		0.147	Kloverpris, 2009
	Electricity	Wh	-	-	178.4	MB brewer	127	Cimini & Moresi, 2016***	127	Cimini & Moresi, 2016***
	Steam	MJ	-	-	-	-	0.006	Amienyo & Azapagic, 2016	0.006	Amienyo & Azapagic, 2016
	Light fuel oil	kg	-	-	-	-	0.0344		0.0344	
	Diesel fuel	kg	-	-	0.049	MB brewer	-	-	-	-
	Water	l	2.78	P brewer	15	MB brewer	4.59	Cordella, 2006	4.59	Cordella, 2006
	Diatomaceous earth	g	-	-	-	-	1.12	Cimini & Moresi, 2016	1.12	Cimini & Moresi, 2016
	Carbon dioxide	g	-	-	14	MB brewer	-	-	-	-
	Phosphoric acid (50%)	g	-	-	-	-	2	Amienyo & Azapagic, 2016	2	Amienyo & Azapagic, 2016
	Sodium hydroxide (50%)	g	-	-	-	-	9		9	
	Sulfuric acid (63%)	g	-	-	-	-	2.5		2.5	
	Firewood production and combust.*	kg	2.16	P brewer	-	-	-	-	-	-
	Glass packaging	g	-	-	-	-	439	Cimini & Moresi, 2016	439	Cimini & Moresi, 2016
	Steel packaging (kegs)	g	-	-	3.2	MB brewer	-	-	-	-
	OUTPUTS									
	Pito	l	**1**	-	**-**	-	-	-	-	**-**
	Beer	l	-	-	**1**	**-**	**1**	**-**	**1**	**-**
	Spent grains	kg	0.42	MB brewer	0.336	MB brewer	0.19	Cimini & Moresi, 2016***	0.19	Cimini & Moresi, 2016***
	Carbon dioxide (biogenic)	g	28.5	MB brewer	28.5	MB brewer	28.50	MB brewer	28.50	MB brewer
	Untreated wastewater	kg	1.14	MB brewer	12.1	Steffen, 1989	-	-	-	-
	Treated wastewater	kg	-	-	-	-	2.93	Steffen, 1989	2.93	Steffen, 1989
	COD, Chemical Oxygen Demand (untreated)	mg	4,562	Steffen, 1989	48,325	Steffen, 1989	-	-	-	-
	COD, Chemical Oxygen Demand (treated)	mg	-	-	-	-	1,467	Hospido, 2005	1,467	Hospido, 2005
	Phosphate	mg	4.56	Steffen, 1989	48	Steffen, 1989	2.93	Steffen, 1989	2.93	Estimation from Steffen, 1989◊
	Steel packaging (kegs) market for scrap steel	g	-	-	3.2	MB brewer, Cimini, 2016**	-	-	-	-

*for inputs and outputs see table 6.7;
**Adapted from Cimini and Moresi, 2016, apportioning from a 30 L capacity keg weighing 9600 g to a 18 L capacity keg 9,600g•18/30=5760g))/100 reuses;
***Also Guidance Note for establishing BAT in the brewing industry (The brewers of Europe, 2002). ◊Assuming water treatment plant, estimation of a reduction of 75% of Phosphate load in wastewater compared to untreated water (no specific data of Phosphate from treated wastewater from breweries could be found).