Investigating environment-related migration processes in Ethiopia – A participatory Bayesian network

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ABSTRACT
The influence of environmental change on human migration is complex. Despite major strides in understanding the environment’s role in migration processes, uncertainties associated with multi-scale factor interactions and their influence on migration still persist. This study aims to (a) understand how soil degradation and rainfall changes – in combination with socio-economic factors – in the northern Ethiopian highlands contribute to human decisions to migrate; and (b) identify barriers for adopting local policy measures to reduce migration needs. Therefore, we integrate place-based research with literature findings and the participatory development of a Bayesian network (BN) involving local policy makers and representatives from both villages and NGOs. Our results show two major influential factors that affect environment-related migration: (a) the sufficiency of a household’s agricultural production and (b) non-farm activities. According to our participatory BN, we conclude that environmental changes increase migration, either through high migration needs due to low agricultural production and/or through increased non-farm activities, which increases the necessary financial means to enable migration. We conclude that contradicting policy programs greatly hinder local measures to prevent soil degradation, potentially fueling migration, and that bottom-up and locally adapted strategies are particularly promising for sustainable land management in the region.

Introduction
Environmental changes such as drought and soil degradation pose an increasing risk for people’s livelihoods, especially those depending on natural resources in the Global South. These changes may influence migration both directly, e.g., by compelling people to leave in the event of natural hazards, and indirectly by affecting socio-economic factors that could both, trigger and hamper migration (Foresight 2011). In recent years, there have been major strides in understanding the potential impacts that environmental changes have on migration, which is largely the result of theoretical enhancements, in-depth field research and the availability of improved datasets (McLeman 2013, 2017; Hunter et al. 2015; Neumann and Hilderink 2015). However, significant uncertainties, limited data and mono-causal narratives regarding the environment-migration nexus still persist in both academic studies and public discourses (Bettini 2013; Hermans and Ile 2019).

Sub-Saharan Africa is particularly important for environment-related migration, as it is vulnerable to climate and environmental changes and has some of the largest intra-continental migration flows globally (Abel and Sander 2014; IPCC 2014; Olsson et al., 2019). Here, we use Ethiopia’s northern highlands as a case study for analyzing linkages of environmental change and migration given the regions’ exposure to high rainfall variabilities and soil degradation (Meshesha et al., 2014; Mekonen and Berlie 2020). In addition, the region has experienced high out-migration rates in the past (CSA 2007) and is a potential Ethiopian hotspot for future rural out-migration due to environmental changes (Hermans-Neumann et al. 2017; Rigaud et al., 2018). However, there is no scientific consensus on the direction and magnitude of environmental change and its interaction with non-environmental factors in African migration processes, including those in northern Ethiopia (Neumann and Hermans 2017; Borderon et al., 2019). This requires innovative approaches for advancing the knowledge base in this field.

Recently, participatory and interdisciplinary approaches such as mobility mapping (Lu et al., 2016 Safra De Campos et al. 2017) and Bayesian networks (BNs) (Drees and Liehr 2015; Andriatsitohaina et al., 2020; Dufhues et al. 2020) have been used to shed light on the complex inter-actions of migration drivers by also involving the people concerned. This potentially allows mutual learning processes between scientists from different disciplines, practitioners and people affected, and thus, helps to reduce vulnerabilities, support bottom-up decision making and counter mono-causal migration narratives.

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In this study, we build on such approaches by integrating the findings of in-depth qualitative fieldwork and literature-based evidence to develop a BN that depicts subsistence farmers’ migration decisions in the context of environmental change in the northern highlands of Ethiopia. BNs allow tackling the complexity and multi-causality of environment-related migration in a very illustrative and straightforward way, and hence can serve as a communication tool and can facilitate stakeholder involvement in research processes (Sun and Müller 2013). We used our BN during a stakeholder workshop to discuss our findings and pressing issues of environment-related migration, to study the relative importance of direct and indirect drivers of environment-related migration and to improve our understanding thereof in the northern highlands. Subsequent to this stakeholder workshop, we used the plurality of gained insights to discuss barriers for adopting local policy measures, more explicitly soil and water conservation (SWC) measures that aim to reduce soil degradation – a pressing environmental issue in the region that fuels migration needs of local subsistence farmers. Overall, our study contributes to a better understanding of environment-related migration processes, discusses leverage points for reducing migration needs and presents specific methodological recommendations to complement the existing toolkit in the environment-related migration research field.

Environmental change, livelihoods and migration in South Wollo

This study was conducted in the rural areas of the South Wollo Zone in the northern highlands of Ethiopia (Figure 1), which is a global hotspot of increasing climate variability, crop yield reduction and ecosystem change (Piontek et al., 2014). Specifically, fluctuating season duration, season onsets and rainfall intensities and their amounts are frequently reported (Bewket 2007b; Rosell 2011; Mekonen and Berlie 2020). In South Wollo, rainfall shows a bimodal pattern, with a main summer season called Kiremt, and a smaller and increasingly variable spring season called Belg. In addition, severe top soil and gully erosion and declining soil fertility due to climatic changes and land mismanagement are widespread (Morrissey 2013; Meshesha et al. 2014; Adimassu et al., 2017; Mekuriaw et al., 2018).

Farmers’ livelihoods in South Wollo depend mainly on keeping livestock and rain-fed cropping with low levels of agriculture inputs. In the higher elevated regions, farmers refrain from cropping during the Kiremt season given the low temperatures combined with high precipitation intensity, which makes those farmers fully dependent on the Belg season. Thus, Belg-dependent farmers, compared to Kiremt farmers, have reduced options for livelihood diversification. In addition, smaller rainfall amounts for cropping and a comparatively less predictable season make Belg farmers exceptionally vulnerable to environmental changes (Rosell and Holmer 2007; Groth et al., 2020). The two major environmental changes – increasing soil degradation and increasing precipitation variability – alongside with others such as frost, hail, crop pests and livestock diseases, increasingly curtail the central livelihood assets of people depending on natural resources since they frequently cause crop failures and livestock loss. Moreover, the densely populated region (148 persons/km2 in 2007) belongs to one of the most food-insecure regions in the country (CSA 2007; Bezu and Holden 2014) and the growing population (2.6% in 2018) is increasing the pressure on scarce land resources.
(Mesheha et al. 2014; World Bank 2018). Besides, weak governance structures and rare employment opportunities are particularly common in the South Wollo rural areas (Ayenew 2002; World Bank 2005; Little et al., 2006).

Consequently, farmers in the northern highlands are a particularly vulnerable group in Ethiopia. In South Wollo, farmers apply various strategies to address these unfavorable conditions including livestock and crop management (e.g., drought-resistant crops), soil and water management (e.g., terracing) and in situ income diversification and migration (Meze-Hausken 2000; Gilligan et al. 2008; Gebrehiwot and Van Der Veen 2013; e.g., Adimassu et al. 2017). In our study region, migration is a widely applied household strategy that appears in various forms, such as temporary and permanent, and to rural and urban destinations inside and outside Ethiopia (e.g., Gray and Mueller 2012; Morrissey 2013; Hermans and Garbe 2019). Many scholars conclude that environmental deterioration and climatic changes in the Ethiopian highlands tend to increase migration propensity (mainly due to reduced agricultural productivity), although there are barriers to migration such as gender norms or economic resources (Ezra 2001; Gray and Mueller 2012; Yohannes and Kebede 2013; Bezu and Holden 2014; Mersha and Van Laerhoven 2016; Wondimagegnhu and Zeleke 2017; Hermans and Garbe 2019). Other studies from South Wollo highlight the importance of environmental, economic and social resources, including social networks, as enabling factors for migration (e.g., Asfaw et al. 2010; Tegegne and Penker 2016; Groth et al. 2020). They conclude that, for instance, years with sufficient rainfall, using the Kiremt season, higher agricultural productivity and non-farm income activities contribute to increased economic household resources that can be used to migrate.

Our participatory approach
We performed a participatory approach to derive an increased understanding of the interplay and direction of influential factors that drive environment-related migration. Our approach integrates knowledge derived from in-depth qualitative fieldwork, academic literature and a stakeholder workshop to develop a BN displaying migration decisions of subsistence farmers in South Wollo (Figure 2). Our study focuses on the perception of farmers and stakeholders on the potential influential factors for migration (e.g., perceived level of soil degradation), as studies from the northern Ethiopian highland showed that perceptions are crucial to understand migration behavior (e.g., Meze-Hausken 2004; Adimassu et al., 2013; Mekonnen et al., 2018).

BNs are probabilistic models representing a set of variables (in our case factors that influence migration) and their conditional dependencies on one another (aka interlinkages). BNs consist of (a) a directed acyclic graph of nodes (i.e., influential factors) connected by edges (i.e., statistical relationships between two influential factors) and (b) conditional probabilities for each variable given its parents in the graph (Aguilera et al., 2011). Each influential factor has a set of mutually exclusive states. BNs enable modelling complex and multi-causal systems of many variables in an efficient and illustrative way, and are therefore a valuable tool for analyzing migration drivers. Recently, participatory research efforts developed expert-based BNs using interviews, questionnaires and workshops for a range of sustainability aspects, including food insecurity (Kleemann et al., 2017) and land use change (Celio and Grét-Regamey 2016). In particular, their straightforward visualization makes BNs a useful communication and learning tool. We used the software Netica version 6.04 (Norsys Software Corp. 2019) to set up and analyze the BN and to demonstrate it during the workshop.

Bayesian network structure
To develop our BN structure we first identified potential influential migration based on the results of an empirical study conducted by Groth et al. (2020) comprising 42 semi-structured household interviews, 18 focus group discussions, five expert interviews and 20 migrant interviews in six kebeles (the smallest Ethiopian administrative unit) in South Wollo (Figure 1). We combined the influential factors – namely non-farm activities, migration experience in the social network and agricultural production – that Groth et al. (2020) identified, with additional literature-based knowledge from the Ethiopian highlands to develop our BN structure. The BN structure displays which influential factors interact and directly or indirectly influence migration decisions of rural subsistence farmers in South Wollo. Here, we focused on household push and enabling factors of migration for employment or sustenance motives in the context of environmental changes. Push factors for migration are factors increasing migration need, whereas enabling factors increase people’s migration ability (e.g., Black et al., 2011; Carling and Schewel 2018).

Participatory quantification of Bayesian network
In March 2019, we conducted a two-day workshop in South Wollo, Amhara, with kebele and district officials (the same individuals involved in the empirical work of Groth et al. (2020)) and NGO representatives. During this workshop, we introduced the BN method to the workshop participants to generate a sound understanding of the BN structure and its purpose. At the beginning of the workshop, the BN did not contain any information on the factors’ direction or magnitude, neither on the magnitude of the linkages between the
factors and consequently on how they influence migration. Within BNs, the magnitude of linkages between factors is expressed with co-called conditional probability tables (CPTs). We used questionnaires to determine the CPTs during our workshop (Figure 3). Therefore, each workshop participant received a questionnaire where they had to answer two different types of questions for each influential factor (see questionnaire in appendix I). The first question for each factor concerned in what state a factor was more likely, dependent on the state of its parent influential factors. For instance, participants were asked if they thought that under good environmental conditions for agriculture and ample (high) availability of job opportunities a household was more likely to be engaged in non-farm activities or more likely not to be engaged in non-farm activities. The second question aimed to quantify the probability for the situation described in the first question by asking how many households out of 10 would be in the situation described in the first question. For instance, if
a participant answered that under good environmental conditions and with ample job opportunities 8 out of 10 households would engage in non-farm activities, we derived an 80% probability for the described linkage between the three factors. In that way, for each influential factor, each respondent provided a probability for a certain situation to happen. We averaged the responses (probabilities) across all participants for each influential factor and populated the CPTs with this information. In our case, households were engaged in non-farm activities with an average probability of 76.7% if job opportunities were ample (high) and environmental conditions for agriculture were good (and with 23.3% they did not engage in non-farm activities under the same conditions) (Figure 3). As a result, each influential factor has its own CPT based on the participant's responses. We determined the number of questions according to Cain et al. (2001). To avoid biasing participants' opinions, we had the participants fill in the questionnaires on their own. However, this can result in contradictions within one filled-out questionnaire meaning that the participants' answers were not logically related (for more detail see appendix 2 in Cain 2001). We dropped illogical answers and used the average of all remaining answers to quantify the BN. On average, 79% of the answers per question were logical and we hence used them for calculating the conditional probabilities. As a last step, the BN software uses the information of the CPTs to calculate the joint probabilities (for details see Jensen and Nielsen 2007) (Figure 3). The resulting quantified BN indicates the probability distribution of all influential factors depending on their parent influential factors. We neither populated our BN with external data nor validated our BN with subsets of our own data as it is typically done for making predictions (e.g., Marcot et al., 2006). In this study, our aim was to use our BN as a communication and learning tool to understand the stakeholders' perspectives. As such, the conditional probabilities displayed in our final BN are fully based on the questionnaires conducted during the workshop.

**Direction and impact of migration drivers**

The resulting quantified BN illustrates the directional influence and the relative importance of the migration drivers as perceived by the workshop participants. Finally, we used the quantified BN in the workshop as a communication facilitator to visualize and discuss the impacts of the changes in influential factors on migration. To complement this, we ran sensitivity analyses of the quantified BN to assess the extent to which the factors influence each other. In particular, we used the sensitivity measure entropy reduction as provided by Netica (Norsys Software Corp. 2019). The higher the entropy reduction of factor B due to information of factor A, the higher is the influence of factor A on factor B. In other words, the more sensitive is factor B toward factor A. We differentiated between three levels of influence, given that our BN is limited to a maximum of three influential factors per variable. The most influential factor is the one that caused the highest entropy reduction and the least influential factor is the one that caused the lowest entropy reduction (see Figure 4).

**Leverages to reduce migration needs**

We used the insights from the stakeholder workshop as a basis to discuss entry points and barriers for local policy measures to address pressing environmental issues and reduce migration needs in South Wollo. We focused on soil degradation because the BN had identified it as one of the most important factors

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**Figure 3.** The Bayesian Network's participatory quantification. We used questionnaires to determine the probabilities specified in the Conditional Probability Tables (CPTs). CPTs express the magnitude of the linkages between influential factors. Each row in a CPT determines the probability that a factor (e.g., non-farm activities) is in a certain state (e.g., yes) depending on the state of its influential factors (e.g., if job opportunities are ample (high) and environmental conditions are good, then 76.7% of the households are engaged in non-farm activities). The joint probabilities were calculated based on the CPTs by using Netica (Norsys Software Corp. 2019).
influencing migration. In this paper, we discuss the barriers for subsistence farmers to adopt SWC measures – one of the most important local policy measure to address soil degradation in South Wollo – and conclude with recommendations for action based on the plurality of stakeholder perceptions.

A Bayesian network on migration drivers

Interlinkages of migration drivers

In our study, migration was defined as the decision to leave one’s household for more than one month, excluding migration for purely educational or marital purposes (cf. Groth et al. 2020). The direct and indirect influential factors we included in the BN can be categorized into four different groups: household opportunities, environmental, livelihood and social factors (Table 1 and Figure 4). Being aware of the multi-causal nature and complexity of migration decisions, we had to limit the number of possible influential factors and their states to allow for meaningful discussions during our stakeholder workshop. In the following section, we describe the assumed interlinkages between the migration drivers for our BN structure and their potential directions. For selected interactions, on which the literature-based evidence lacks consensus, we describe two possible directional influences. We use the BN quantification from the workshop to understand the mixed evidence on the directional influence of migration drivers rather than specifying the directional influence in the BN prior to the workshop (see section 4.b).

Figure 4 shows the developed BN on migration drivers. Starting from the center of the network, agricultural production is a direct influential factor for migration given its central role for the livelihoods of subsistence farmers in South Wollo. Agricultural production covers cropping and keeping livestock at the household level. We assumed that whether the agricultural production is sufficient to fulfill the household’s subsistence needs affects migration decisions, as earlier studies confirmed (e.g., Tegegne and Penker 2016). However, the influence’s direction on migration can be contrasting. On the one hand, if a household cannot fulfill its food demand by agricultural production, household members might choose to migrate to diversify their income activities.

Figure 4. The Bayesian Network of the current state of environment-related migration of subsistence farmers in South Wollo. The numbers beside the states represents the percentage of households that are in the respective state. The horizontal bars visualize these percentages. The color of the arrows indicate the relative importance of one influential factor (parent node) on another influential factor (child node) based on the sensitivity analysis.
Table 1. Definition and states of BN influential factors (for more details see also appendix II).

| Factor                          | Definition                                                                 | States          |
|--------------------------------|---------------------------------------------------------------------------|-----------------|
| Soil degradation               | Reduced capacity of the soil to provide goods and services for human well-being mainly driven by soil erosion, i.e., the loss of topsoil and nutrients. Soil erosion can be caused by natural hazards such as intensive rainfall and/or by land mismanagement. | Low/High        |
| Precipitation variability      | This factor covers one or more of the following aspects: fluctuating season duration, start and end dates of rainy seasons, rainfall intensities or amount of rainfall. | Low/High        |
| Rainy season                   | Rainy season used for cropping activities.                               | Belg/Kiremt/Both|
| Environmental condition for agriculture | A measure of agricultural suitability, it comprises soil degradation, precipitation variability and which rainy season(s) are/is used for cropping. | Poor/Good       |
| Availability of technologies   | Availability of technologies such as SWC measures (e.g., terracing, check dams, shrubs), agricultural inputs (e.g., fertilizer) and loans. | Yes/No          |
| Land availability              | The ratio of land size (including owned, rented and sharecropped land, and cultivated land) to the number of household members. | Low/High        |
| Job opportunities              | The chances for household members to find work besides cropping and keeping livestock. This is determined by the remoteness of the place of residence, i.e., distance to the next street or market, as well as the access to and the labor market demand, i.e., distance to the next big city. | Low/High        |
| Agricultural production        | Amount of agricultural products produced by the household. This includes cropping and livestock farming, but not forest products. | Not-sufficient/Sufficient |
| Non-farm activities            | The household activities that are beyond cropping and keeping livestock such as wage and daily labor (e.g., construction work), running a cafeteria and growing/selling eucalyptus trees. | Yes/No          |
| Personal attitude toward migration | The opinion and beliefs of a person regarding migration. This depicts whether the person thinks of migration as something desirable or something to avoid. | Positive/Negative |
| Social norm                    | The village community’s informal understanding of migration. This depicts whether the members of the village community see migration as something desirable or something to avoid. | Positive/Negative |
| Migration experience in social network Migration | The access to the migration experience of family members, neighbors or friends. This comprises out-migration from rural South Wollo to rural or urban destinations. It includes short-term/distance (e.g., seasonal migration to nearby towns) and long-term/distance migration (e.g., to Saudi Arabia) of a household member (for at least one month, excluding migration for purely marital and educational attainment). | Available/Not available |

elsewhere to fulfill the household’s needs. On the other hand, insufficient agricultural production can reduce the household’s economic resources and as such can also inhibit migration (e.g., Gray and Mueller 2012).

Agricultural production itself is influenced by several factors, including the availability of agricultural technologies and loans (Asfaw et al. 2010). In addition, we accounted for the severe and increasing land scarcity, which hampers the agricultural production of farmers in South Wollo (e.g., Mesghela et al. 2014) by including land availability as another influential factor of the agricultural production. Land availability is measured as the ratio of land size (including owned, rented and sharecropped land) and household members. The third influential factor of agricultural production is the condition of the environment, which accounts for a combination of soil degradation, precipitation variability and the type of rainy season used for cropping. First, soil degradation, which is mainly driven by soil erosion due to mismanagement and/or natural hazard, results in the soil’s reduced capacity to provide goods and services for human well-being, including food and fodder. Second, precipitation variability, which comprises the fluctuation of rainfall patterns from year to year, including fluctuating season duration, start and end dates and rainfall intensities or amount of rainfall, adversely affects agricultural production. The third environmental condition is the rainy season and we distinguished between Kiremt and Belg season, given their different levels of variability and influence on agricultural production. In principle, a household that uses the Kiremt season for cropping can rely on more stable and higher rainfall amounts than a household that solely depends on the Belg season. As such, households using the Kiremt rains usually have more options for crop diversification and are more likely to produce more food and fodder as compared to a household that exclusively uses the Belg season.

Besides agricultural production, non-farm activities are central for the livelihoods in rural South Wollo and directly influence migration (Groth et al. 2020). We argue that if a household’s agricultural production is restricted by adverse environmental conditions, the household will look for non-farm activities such as wage and daily labor to fulfill its needs. This may increase a household’s financial resources and thereby motivate a (costly) migration decision (cf. Groth et al. 2020). Engaging in non-farm activities is itself influenced by employment opportunities in the place of residence and differs among localities due to distance to roads, markets and cities.

The final group of migration drivers in the BN accounts for social factors influencing migration decisions. Whether one opts for or against migration is
related to one’s personal attitude, including norms and opinions regarding migration (De Jong 2000). Here, we considered two factors as identified from the literature and our fieldwork that mainly drive this attitude: migration experience within one’s social network and social norms within the village communities. Migrating family members can be strong incentives for migration, since they tend to reduce migration risks and costs and enhance migration desires (e.g., McLeman and Smit 2006; Groth et al. 2020). Nevertheless, whether migration as an accepted strategy within a community strongly mediates migration decisions (e.g., Martin et al., 2014). For instance, if the community views migration is a chance to ‘improve life’ and a person has a family member living outside their own community, migrating to this region may be considered preferable.

During our stakeholder workshop, we used breakout groups to let the participants discuss the BN structure and to add or delete influential factors respectively. In general, the participants strongly agreed with our proposed BN structure (see appendix II).

The state and impact of migration drivers

Based on the questionnaires, we first quantified the current state of soil degradation, precipitation variability, use of rainy season, land availability, availability of technologies, job opportunities, social norm and migration experience in South Wollo. Second, we quantified the conditional probabilities, i.e., the probability of an influential factor being in a certain state given the states of their parent influential factors (e.g., the probability of having good environmental conditions for agriculture under the condition that soil degradation is high, precipitation variability is low and the Belg season is used for cropping).

The BN shows that the environmental conditions for agriculture are currently in a poor state. Soil degradation and precipitation variability are both high for the majority of households in South Wollo, with more than 20% of households exclusively relying on the small Belg rainy season. We also see limited livelihood opportunities for households given low land availability and few job opportunities for the majority of households. Technologies such as SWC measures and agricultural inputs are available to about 50% of households in South Wollo. Furthermore, we found that nearly three out of four households have access to migration experiences via their social network and that migration is seen as desirable by 60% of the village communities.

The quantified BN shows in which direction factors influence migration, their relative importance and their interlinkages (Figure 4 and Table 2). The sensitivity analysis with Netica – which is used to study the influential factors’ relative importance on migration – showed that the sufficiency of agricultural production most strongly influenced migration. Presumably, low agricultural production increases migration because migration pressure is high with low availability of food and income from agriculture. Agricultural production in turn is highly influenced by the environmental condition, which is adversely impacted by high precipitation variability and high soil degradation. This is highlighting the agricultural channel via which climatic changes often influence migration of people who depend on natural resources (Falco et al. 2019). Compared to soil degradation and rainfall variability, the stakeholders ranked the rainy season’s impact on the environmental condition lower. This might have been caused by the fact that numerous participants considered this to be part of the rainfall variability factor, given that seasons are determined by their variability and amount of precipitation. Furthermore, the impact of the availability of technologies on agricultural production was low. This is likely caused by households’ lack of adopting technology, by inappropriate design or application of these technologies or by the overriding impact of the environment’s condition, e.g., terracing cannot compensate for an extremely deteriorated environmental state. Moreover, the state of land availability only minimally influences agricultural production. This somehow contrasts other studies that indicate land scarcity is often a strong migration driver in the northern highlands (Asfaw et al. 2010; Gray and Mueller 2012; Morrissey 2013). However, in those studies, land scarcity was often described as direct motivation to migrate especially for landless young people in the rural areas. Yet, in our BN, land availability is an indirect influential factor that impacts migration via agricultural production (Falco et al. 2019). This missing direct link to the migration decision is likely to cause the lower than expected influence. Furthermore, land availability’s impact is overridden by the current poor state of the environmental condition, i.e., the land holding size under deteriorated environmental conditions does not matter substantially.

Moreover, migration decisions are – although to a lower extent – driven by household members’ engagement in non-farm activities, which in turn is strongly dependent on the availability of job opportunities. According to our BN, adverse environmental changes increases non-farm activities possibly because the higher need for additional income sources given the poor environmental conditions and hence the insufficient agricultural production. Our results suggest that non-farm activities lead to an increase in migration. This contradicts Meze-Hausken’s (2000) findings, who mentioned that non-farm activities could also alleviate the migration pressure and showed that households ‘with more survival strategies tend to resist distress migration longer than those having only few survival strategies’ (Meze-Hausken 2000, p. 397). According to our results, migration is caused by either the increased
migration ability due to more economic resources and/or by the higher migration pressure caused by insufficient agricultural production.

Finally, our results show that under sufficient agricultural production, an increase in non-farm activities reduces migration. We argue this is due to the overall low migration need and because people might have little aspirations to migrate when they have a job. That way, non-farm activities are not an enabling factor as under insufficient agricultural production, but rather become a ‘bonding factor’. However, if non-farm activities are reduced, especially the younger household members start to search for job opportunities elsewhere, despite the sufficient agricultural production, and consequently, migration increases. This assumption is based on the interviews conducted during the empirical field work showing that younger people in rural South Wollo have strong aspirations to work elsewhere. It is also in line with Bezu and Holden’s (2014) findings, who showed that the Ethiopian youth have minimal interest in a rural livelihood and thus, rural-urban migration is very common among them.

Overall, the BN revealed no clear-cut relationship between environmental factors and their influence on migration, which illustrates their complex dynamic. Nevertheless, we can conclude that environmental changes – in particular increasing soil degradation and precipitation variability – increases migration, either through high migration needs due to low agricultural production and/or through increased non-farm activities that enable migration through financial means. This supports findings that migration can be both a risk-coping strategy for poor households and an asset-accumulation strategy for better-off households (e.g., Asfaw et al. 2010).

Compared to the sufficiency of agricultural production and the engagement in non-farm activities, the personal attitude has little influence on migration. Hence, the importance of social factors highlighted in the literature (e.g., Brown and Tilly 1967; De Haas 2010) was not reproduced with our BN, most likely due to uncertainties regarding the definition of migration. The workshop revealed the challenge to generalize migration connotations as this strongly depends on the type of migration (i.e., internal, external, legal, illegal). This explains stakeholders’ vague and diverging answers, and consequently, the impact of the personal attitude on migration is little in the BN. Another reason for this low impact could be that households sent family members away to reduce livelihood risks. The greater the pressure on a household, the less it matters whether an individual family member perceives migration as an opportunity or a risk. Nevertheless, our results show that the individual perception of migration is positively influenced by the migration experience available in the household’s social network. This is in line with findings that examined the positive influence of network effects and information flows on migration, arguing that migrant networks reduce migration’s risks and costs (e.g., Asfaw et al. 2010; Bylander 2015; Wondimagegnehu and Zeleke 2017). Finally, the impact of the village community’s informal understanding of migration on a person’s migration perception is rather small in the BN. Again, this is partly caused as the migration experience’s impact overrides the village communities’ understanding, i.e., if there is a migration experience in the social network, the village community’s opinion influences the individual perception less strongly than without a migration experience available.

### Table 2. Impact of influential factors on migration in the quantified Bayesian Network as based on the participants’ answers.

| Influential factor                                      | Impact on migration | Likely explanation                                                                 |
|---------------------------------------------------------|---------------------|-------------------------------------------------------------------------------------|
| Insufficient agricultural production                    | Increase            | If the household cannot fulfill its needs by agricultural production, household members might migrate to earn additional income to fulfill the household’s needs. |
| Household members engaged in non-farm activities        | Increase            | Performing activities beyond cropping and keeping livestock, such as selling eucalyptus, might affect a household’s financial resources and thereby also enable migration. |
| Positive personal attitude toward migration              | Increase            | The personal attitude directly influences migration decisions.                      |

- **Factor interactions**

- **Under the condition of sufficient agricultural production, an increase in non-farm activities leads to less migration**

- **High soil degradation**

- **Increase**

  - High soil degradation leads to poor environmental conditions for agriculture. Poor environmental conditions a) lowers the agricultural production and b) increases non-farm activities. The latter occurs mainly because of higher needs for additional income sources to compensate low agricultural production rates. Together, a high soil degradation increases migration needs.

- **Ample job opportunities in South Wollo**

- **Increase**

  - Increases non-farm activities, which enables migration
Leverage to reduce migration needs in South Wollo: soil and water conservation (SWC) measures

We used our BN to discuss major migration pathways with the participants during our workshop and the possibilities for local policy measures to reduce livelihood risks in South Wollo. Results of our sensitivity analysis show that agricultural production is the major driver of migration, which in turn is mainly driven by precipitation variability and soil degradation (see section 4b and Figure 4). The workshop discussions confirmed that declining agricultural production rates are posing increasing risks for farmers and, combined with limited job opportunities in rural South Wollo, increasing subsistence farmers’ migration needs (see section 4b). Stakeholders agreed that local measures to circumvent or adapt to the increasing fluctuations in precipitation are limited, whereas possibilities for combating soil degradation are considered more promising. SWC is a common approach of locally implemented measures – including biological measures such as tree planting or grass strips and physical measures such as check dams – to rehabilitate degraded soils, foster sustainable land management and improve agricultural yields in Ethiopia by involving the entire community in implementing the respective measures (Bewket 2007a; FDRE 2014; Haregeweyn et al., 2015).

Institutionalized SWC efforts were introduced in the early 1970s in Ethiopia and since then large programs, such as the Food-For-Work (1973–2002) and the National Sustainable Land Management Project (SLMP) (2008–2018) were initiated with various donors’ support (see Haregeweyn et al. 2015 for a detailed overview). However, despite these enormous efforts, there are several barriers that hamper farmers’ adoption of SWC measures. Here, we draw on the plurality of our workshop participants to discuss adoption barriers, which need to be addressed to secure livelihoods and reduce migration pressure for subsistence farmers in South Wollo.

Our workshop participants highlighted the lack of information and awareness regarding soil degradation and related SWC efforts as one of the major barriers for SWC adoption. They emphasized that awareness-raising has to be the core objective to enhance SWC, e.g., with establishing demonstration sites within the communities. Wordofa et al. (2020) recommend to focus SWC efforts on the better experienced farmers and use those with larger plots as model farmers to demonstrate SWC measures. These demonstration sites can help to scale up SWC and therewith, increase adoption rates of the less-experienced farmers, step by step.

As a further hurdle, the workshop participants mentioned the lack of resources, especially financial ones, to afford materials, e.g., to build terraces and check dams. Non-farm activities and loans for subsistence farmers, e.g., to start small-businesses, could increase the financial means of subsistence farmers and thus, constructing SWC structures. However, our BN revealed that for 62% of the households in South Wollo, job opportunities are rare (see Figure 4). Moreover, the lack of jobs and income is not only a hurdle to build SWC measures, but also they increase migration needs as they hinder the diversification of income sources to compensate for deficits in agricultural production. In addition, limited financial means in principle reduce people’s capabilities to engage in costly migration, which in turn increases the risk of becoming trapped in vulnerable environments (cf. Groth et al. 2020). Consequently, creating income sources is critical to a) reduce migration needs, b) enable investments in (durable) SWC measures and c) increase agency in migration processes.

Further, a lack of institutional support from extension agents reportedly hampers implementing SWC measures, which confirms earlier findings (Tefera and Sterk 2010; Adimasu et al. 2013). Extension agents are overwhelmed with the workload that comes along with the participatory and integrated watershed development approach. Improved financial and human resources, as well as practical and communication skills, are therefore needed to enable extension agents to effectively support rural communities in implementing SWC measures (Belay and Abebaw 2004).

Land tenure insecurity was another factor identified as favoring soil degradation as it arguably reduces smallholders’ incentives to increase efforts to conserve soils. This is in line with Gebremedhin and Swinton (2003) and Bewket (2007a) who observed its negative influence on adoption, given that insecure and short-term use rights are less likely to motivate durable but more costly measures compared to long-term use rights. This suggests that securing tenure for farmers, e.g., increasing land transferability, enhances sustainable land management (e.g., Ali et al. 2011).

A similar issue was raised regarding the inappropriateness of SWC measures to the local conditions. The stakeholders mentioned that promoted activities such as compost or grazing restrictions are often not feasible for farmers, given the lack of materials (plant residues, cow dung) and the knowhow to produce compost or alternative grazing land for their livestock. In a region where rural livelihoods are under constant pressure, through e.g., food insecurity and population pressure, grazing restrictions should be used very carefully. If restrictions are enforced, they need to be complemented with options for livelihood diversification, for instance with cut and carry systems where farmers have access to the closed areas for collecting fodder. Bewket (2007a) also mentioned SWC measures’ inappropriateness and found that the design of some measures was too narrow and hindered the plausible activities, or that measures were
simply too land- and labor-consuming. Our results show that 69% of the households in South Wollo face land scarcity (Figure 4), making well-designed and less land-consuming measures even more relevant.

Another major barrier, though not discussed during our workshop, is the lack of labor to implement and maintain SWC schemes. Several scholars showed that farmers are less inclined to build and maintain labor-intensive schemes – especially in insecure tenure systems – when these measures’ benefits emerge in the long term (Adimassu et al. 2013; Nigussie et al. 2018). In addition, the participants raised the issue of farmers lacking trust toward the government, given the government’s top-down approach to promote SWC. The top-down implementation is also widely criticized in the literature (e.g., Haregewyyn et al. 2015; Nigussie et al. 2018). Insufficiently integrating local and place-specific knowledge greatly hinders the acceptance of SWC, which in combination with other barriers ultimately hampers sustainable implementation and adoption of SWC measures.

Lastly, there is a fundamental contradiction between the measures to combat soil degradation and the government’s agricultural input packages, which promotes intensifying agriculture, for example through frequent ploughing, and applying artificial fertilizers and pesticides. Workshop participants mentioned that these practices often succeed to increase farmers’ yields in the short term, but also have a high potential to increase soil degradation in the long run, which Taddese (2001) confirmed. Our results show these unsustainable practices increase long-term migration needs as well. Thus, first and foremost, the contradictions in government programs must be urgently resolved to achieve sustainable and integrative land management.

**Methodological reflections**

The stakeholder workshop benefited from the combination of different workshop formats, such as presentations by the first and last author, group discussions, questionnaires and plenary discussions to encourage all participants’ active involvement. Furthermore, through our intensive and continuous collaborative place-based research in the study area throughout recent years, we established a trustful relationship between workshop participants and our research team, which is essential for a successful workshop.

Overall, the participants’ understanding of and agreement with the BN were high. Likely reasons for this were (a) the careful design process of the BN based on insights from extensive fieldwork in the region embedded in scientific literature and (b) the well thought-through knowledge transfer of the BN method and the research insights in the frame of the stakeholder workshop in which participants were encouraged to provide feedback. Yet, despite the open and interactive workshop atmosphere, there was limited criticism on our methods and findings, which was likely the result of cultural norms and the new method introduced. A possible strategy to counteract this in the future is to provide options for anonymous feedback.

Quantifying the BN’s conditional probabilities, i.e., how a change in one influential factor is affecting another influential factor, was hampered by diverging answers across stakeholders and by ontological uncertainty. This includes mainly stakeholders’ difficulties in estimating the impact of factors on other factors, resulting in vague answers with equal probabilities for all states of the influential factor (cf., Sallou et al., 2017). Other scholars encountered similar challenges during participative developments of BNs, for example, the high variance in expert judgements (Kleemann et al. 2017) and the tendency for giving answers around the mean attributed to ‘insufficiently detailed or simply a general problem in questionnaire-based surveys’ (Celio and Grêt-Regamey 2016, p. 19). In our case, the workshop discussions revealed varying notions of the migration term. Most important, the locals’ perception of migration largely depends on whether participants had international, internal or both migration forms in mind. International migration was connoted rather negatively and internal migration rather neutrally, depending on whether it was perceived as a common livelihood strategy, as a ‘last resort’ or as an illegal and risky activity for farmers. Together, this made the quantification of the social influential factors challenging, resulting in a low impact of the influential factors personal attitude and social norm on migration. Such challenges can be minimized by expanding the workshop and thereby supporting (a) a common understanding of terms and concepts in an interactive way and (b) active engagement of all participants to handle diverging answers. Hurdles for participants may further be reduced through one-on-one interviews, such as Kleeman et al. (2017) implemented, rather than group discussions, although they are potentially prone to biases and time-intensive.

Overall, the BN method was a valuable communication tool for visualizing the complex interplay of migration drivers. The BN facilitated group discussions and thereby enabled us to derive an improved understanding of environment-related migration in South Wollo. By comprising various levels of factors, BNs allow delineating the indirect influence of various environmental change factors and assessing their relative strength as crucial migration drivers. For future endeavors, our presented BN could be further developed, e.g. by involving a larger number of participants and applying model testing and validation to use it as a tool for local decision-making in South Wollo (see Marcot et al. 2006).

**Conclusion**

Our study shows how slow-onset environmental changes in South Wollo influence livelihoods and migration dynamics mainly through agricultural production. In particular, perceived increases in precipitation variability and soil degradation enhance migration, either through increased non-farm
activities, which enable migration through economic resources, or through insufficient agricultural production, which increase migration needs. Based on our quantified BN and the discussions with the stakeholders, we found that a major leverage to reduce livelihood and migration pressure is to improve the adoption of SWC measures. We found that a couple of factors – including the top-down approach of implementing SWC measures; the non-integrative implementation of inappropriate, labor-demanding and foremost physical SWC measures; the lack of resources at the responsible institutions combined with contracting governmental programs – hinder sustainable land management in South Wollo, which in turn increases migration pressure. We conclude that to be effective, the design and implementation of SWC measures require active engagement of local extension services, farmers and rural communities. Without considering farmers’ perspectives and knowledge, SWC measures most likely fail, potentially fueling migration. However, to increase farmers’ acceptance and trust requires improving the socio-economic boundary conditions: Our results suggest that securing long-term land use rights, reducing the overall pressure on land resources (e.g., through diversification of livelihoods, integrated SWC measures) and aligning and maximizing synergies between government strategies and programs, are essential to achieve sustainable and integrative land management.

The presented approach illustrates that participatory BNs are suitable to engage stakeholders in research processes and to derive recommendations for actions, which should account for these stakeholders’ needs in the end. In addition, BNs have the potential to be used as supportive tools in decision-making processes, for example by advising local decision-makers on how to foster livable futures for their communities. We conclude that participatory approaches and stakeholder involvement require a) a well-anchored host in the respective region, b) a trustful relationship between the research team and the participants, c) interactive workshop formats to facilitate discussions and feedback, d) a sufficient timeframe to discuss and develop a common understanding of the central terms or to conduct a follow-up workshop to discuss diverging answers and open questions and e) in-depth information on the topic and the region gained either through intensive literature reviews or empirical research. In its entirety, our approach allowed for integrating a wide and heterogeneous knowledge spectrum to tackle a societally relevant and demanding issue.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

I. Questionnaire for the quantification of the Bayesian Belief Network

Name:
Affiliation:
Position:

1. Environmental condition for agriculture

Q1.1.1: Imagine a situation with low soil degradation, low precipitation variability and in which Belg & Kiremt are available as rain seasons. In which state do you think would the environmental condition for agriculture be – poor or good?

☐ poor  ☐ good

Q1.1.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the environmental conditions would be in the state you chose in question Q1.1.1.

—– out of 10

Q1.2.1: Imagine a situation with high soil degradation, high precipitation variability and in which only Belg is available as rain season. In which state do you think would the environmental condition for agriculture be – poor or good?

☐ poor  ☐ good

Q1.2.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the environmental conditions would be in the state you chose in question Q1.2.1.

—– out of 10

Q1.3.1: Imagine a situation with high soil degradation, low precipitation variability and in which Belg & Kiremt are available as rain seasons. In which state do you think would the environmental condition for agriculture be – poor or good?

☐ poor  ☐ good

Q1.3.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the environmental conditions would be in the state you chose in question Q1.3.1.

—– out of 10

Q1.4.1: Imagine a situation with low soil degradation, high precipitation variability and in which Belg & Kiremt are available as rain seasons. In which state do you think would the environmental condition for agriculture be – poor or good?

☐ poor  ☐ good

Q1.4.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the environmental conditions would be in the state you chose in question Q1.4.1.

—– out of 10

Q1.5.1: Imagine a situation with low soil degradation, low precipitation variability and in which only Kiremt is available as rain season. In which state do you think would the environmental condition for agriculture be – poor or good?

☐ poor  ☐ good

Q1.5.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the environmental conditions would be in the state you chose in question Q1.5.1.

—– out of 10

Q1.6.1: Imagine a situation with low soil degradation, low precipitation variability and in which only Belg is available as rain season. In which state do you think would the environmental condition for agriculture be – poor or good?

☐ poor  ☐ good

Q1.6.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the environmental conditions would be in the state you chose in question Q1.6.1.

—– out of 10
2. Agricultural production

Q2.1.1: Imagine a situation with high land size / average HH size (i.e. above 0.5 ha per household), good environmental condition for agriculture and technologies available to the household. Would you think the agricultural production to be sufficient or not sufficient to fulfill household’s subsistence needs?

☐ sufficient  ☐ not sufficient

Q2.2.1: Imagine a situation with low land size / average HH size (i.e. below 0.5 ha per household), good environmental condition for agriculture and no technologies available to the household. Would you think the agricultural production to be sufficient or not sufficient to fulfill household’s subsistence needs?

☐ sufficient  ☐ not sufficient

Q2.3.1: Imagine a situation with low land size / average HH size (i.e. below 0.5 ha per household), good environmental condition for agriculture and technologies available to the household. Would you think the agricultural production to be sufficient or not sufficient to fulfill household’s subsistence needs?

☐ sufficient  ☐ not sufficient

Q2.4.1: Imagine a situation with high land size / average HH size (i.e. above 0.5 ha per household), good environmental condition for agriculture and no technologies available to the household. Would you think the agricultural production to be sufficient or not sufficient to fulfill household’s subsistence needs?

☐ sufficient  ☐ not sufficient

Q2.5.1: Imagine a situation with high land size / average HH size (i.e. above 0.5 ha per household), poor environmental condition for agriculture and technologies available to the household. Would you think the agricultural production to be sufficient or not sufficient to fulfill household’s subsistence needs?

☐ sufficient  ☐ not sufficient

Q2.5.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the agricultural production would be in the state you chose in question Q2.5.1?

—— out of 10

3. Non-farm activities besides cropping and livestock keeping

Q3.1.1: Imagine a situation with ample job opportunities and good environmental condition for agriculture. Would you think a household would be engaged in non-farm activities besides cropping and livestock keeping or not?

☐ yes  ☐ no

Q3.1.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the non-farm activities would be in the state you chose in question Q3.1.1?

—— out of 10
Q3.2.1: Imagine a situation with ample job opportunities and poor environmental condition for agriculture. Would you think a household would be engaged in non-farm activities besides cropping and livestock keeping or not?

☐ yes ☐ no

Q3.2.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the non-farm activities would be in the state you chose in question Q3.2.1?

—— out of 10

Q3.3.1: Imagine a situation with low job opportunities and good environmental condition for agriculture. Would you think a household would be engaged in non-farm activities besides cropping and livestock keeping or not?

☐ yes ☐ no

Q3.3.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the non-farm activities would be in the state you chose in question Q3.3.1?

—— out of 10

Q3.4.1: Imagine a situation with low job opportunities and poor environmental condition for agriculture. Would you think a household would be engaged in non-farm activities besides cropping and livestock keeping or not?

☐ yes ☐ no

Q3.4.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the non-farm activities would be in the state you chose in question Q3.4.1?

—— out of 10

4. Migration

Q4.1.1: Imagine a situation in which the household’s agricultural production is sufficient to fulfill household’s subsistence needs, the household member has a positive personal attitude towards migration and the household is engaged in non-farm activities. Would you think the household member would migrate or not?

☐ yes ☐ no

Q4.1.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the migration would be in the state you chose in question 4.1.1?

—— out of 10

Q4.2.1: Imagine a situation in which the household’s agricultural production is not sufficient to fulfill household’s subsistence needs, the household member has a negative personal attitude towards migration and the household is not engaged in non-farm activities. Would you think the household member would migrate or not?

☐ yes ☐ no

Q4.2.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the migration would be in the state you chose in question 4.2.1?

—— out of 10

Q4.3.1: Imagine a situation in which the household’s agricultural production is not sufficient to fulfill household’s subsistence needs, the household member has a positive personal attitude towards migration and the household is engaged in non-farm activities. Would you think the household member would migrate or not?

☐ yes ☐ no

Q4.3.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the migration would be in the state you chose in question 4.3.1?

—— out of 10

Q4.4.1: Imagine a situation in which the household’s agricultural production is sufficient to fulfill household’s subsistence needs, the household member has a negative personal attitude towards migration and the household is engaged in non-farm activities. Would you think the household member would migrate or not?

☐ yes ☐ no
Q4.4.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the migration would be in the state you chose in question 4.4.1?

--- out of 10

Q4.5.1: Imagine a situation in which the household’s agricultural production is sufficient to fulfill household’s subsistence needs, the household member has a positive personal attitude towards migration and the household is not engaged in non-farm activities. Would you think the household member would migrate or not?

☐ yes  ☐ no

Q4.5.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the migration would be in the state you chose in question 4.5.1?

--- out of 10

5. Personal attitude towards migration

Q5.1.1: Imagine a situation with positive social norm and migration experience available in the social network of the household. Would you think the household member to have a positive or negative attitude towards migration?

☐ positive  ☐ negative

Q5.1.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the attitude towards migration would be in the state you chose in question Q5.1.1?

--- out of 10

Q5.2.1: Imagine a situation with positive social norm and migration experience is not available in the social network of the household. Would you think the household member to have a positive or negative attitude towards migration?

☐ positive  ☐ negative

Q5.2.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the attitude towards migration would be in the state you chose in question Q5.2.1?

--- out of 10

Q5.3.1: Imagine a situation with negative social norm and in which migration experience is available in the social network of the household. Would you think the household member to have a positive or negative attitude towards migration?

☐ positive  ☐ negative

Q5.3.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the attitude towards migration would be in the state you chose in question Q5.3.1?

--- out of 10

Q5.4.1: Imagine a situation with negative social norm and in which migration experience not available in the social network of the household. Would you think the household member to have a positive or negative attitude towards migration?

☐ positive  ☐ negative

Q5.4.2: Imagine that 10 households would be in this situation. Estimate for how many of these ten households the attitude towards migration would be in the state you chose in question Q5.4.1?

--- out of 10

Current state of the entry nodes

1. Soil degradation

Q1.1: What is the current state of soil degradation averaged over all sites in South Wollo? Low or high?

☐ low  ☐ high

Q1.2: Imagine 10 sites in South Wollo. Estimate for how many of these sites the soil degradation on their land is in the state you chose in Q1.1?

--- out of 10
2. Precipitation variability

Q2.1: What is the current state of precipitation variability averaged over all sites in South Wollo? Low or high?

☐ low  ☐ high

Q2.2: Imagine 10 sites in South Wollo. Estimate for how many of these ten sites the precipitation variability is in the state you chose in Q2.1?

—— out of 10

3. Rain season

Q3.1: What is the current state of using rain seasons for cropping in South Wollo? Belg, Kiremt or Both?

☐ Belg  ☐ Kiremt  ☐ Both

Q3.2: Imagine 10 households in South Wollo. Estimate for how many of these ten households use Belg, Kiremt and both seasons?

—— out of 10 use Belg—— out of 10 use Kiremt—— out of 10 use both

4. Land size / HH size

Q4.1: What is the current state of land size / HH size averaged over all households in South Wollo? Low or high?

☐ low  ☐ high

Q4.2: Imagine 10 households in South Wollo. Estimate for how many of these ten households land size / average HH size is in the state you chose in Q4.1?

—— out of 10

5. Availability of technologies

Q5.1: What is the current state of using technologies in South Wollo? Yes or no?

☐ yes  ☐ no

Q5.2: Imagine 10 households in South Wollo. Estimate for how many of these ten households using technologies in the state you chose in question Q5.1?

—— out of 10

6. Job opportunities

Q6.1: What is the current state of job opportunities in South Wollo? Low or high?

☐ low  ☐ high

Q6.2: Imagine 10 households in South Wollo. Estimate for how many of these ten households the job opportunities is in the state you chose in Q6.1?

—— out of 10

7. Migration experience in social network

Q7.1: What is the current state of having migration experiences in households' social network in South Wollo? Available or not available?

☐ available  ☐ not available
Q7.2: Imagine 10 households in South Wollo. Estimate for how many of these ten households migration experience in social network is in the state you chose in Q7.1?

--- out of 10

8. Social norm

Q8.1: What is the current state of social norms regarding migration in South Wollo? Positive or negative?

[ ] positive  [ ] negative

Q8.2: Imagine 10 households in South Wollo. Estimate for how many of these ten households the social norm is in the state you chose in Q8.1?

--- out of 10

II. Definitions and possible states of influence factors

| Factor                          | States                                                                 |
|--------------------------------|------------------------------------------------------------------------|
| Soil degradation                | Low: No or only very little reduction in soil capacity to provide goods and services for human well-being mainly driven by soil erosion, i.e. the loss of topsoil and nutrients  
High: Substantial loss of soil capacity to provide goods and services for human well-being mainly driven by soil erosion, i.e. the loss of topsoil and nutrients |
| Precipitation variability      | Low: Precipitation pattern is almost constant over the years  
High: Precipitation pattern is very different from year to year |
| Rainy season                   | Belg: Only Belg season is used for cropping  
Kiremt: Only Kiremt season is used for cropping  
Bott: Belg and Kiremt season are used for cropping |
| Environmental condition for agriculture | Poor: Disastrous or poor conditions to perform agriculture due to soil degradation, precipitation variability and which rainy season(s) are/is used for cropping  
Good: Very good conditions to perform agriculture due to soil degradation, precipitation variability and which rainy season(s) are/is used for cropping  |
| Availability of technologies   | Yes: Any of the technologies such as SWC measures (e.g. terracing, composting, checkdam, shrubs), availability of agricultural inputs (e.g. fertilizer) and loan is/are available  
No: No technology such as SWC measures (e.g. terracing, composting, checkdam, shrubs), availability of agricultural inputs (e.g. fertilizer) and loan is available |
| Land availability              | Low: Land per average household size is low, i.e. less than 0.5 ha land per household available  
High: Land per average household size is high, i.e. more than 0.5 ha land per household available |
| Job opportunities              | Low: No or only very few possibilities to find work outside agriculture  
High: Several or many possibilities to find work outside agriculture |
| Agricultural production        | Not-sufficient: Agricultural production is not sufficient to fulfill household's subsistence need  
Sufficient: Agricultural production is sufficient to fulfill household's subsistence needs |
| Non-farm activities            | Yes: At least one household member is engaged in non-farm activities such as wage and daily labor (e.g. construction work), running a cafeteria and growing/selling of eucalyptus trees  
No: No household member is engaged in non-farm activities such as wage and daily labor (e.g. construction work), running a cafeteria and growing/selling of eucalyptus trees |
| Personal attitude towards migration | Positive: A person thinks of migration as something that is desirable  
Negative: A person thinks of migration as something that is not desirable |
| Social norm                    | Positive: The village community see migration as something that is desirable  
Negative: The village community see migration as something that is not desirable |
| Migration experience in social network | Available: Migration experience exists in social network (family members, neighbors or friends)  
Not available: No migration experience in social network (family members, neighbors or friends) |
| Migration                      | Yes: Household member leaves one household for at least one month, excluding migration for purely marital or educational purposes  
No: Household member does not leave household for at least one month, excluding migration for purely marital or educational purposes |

Additional influence factors discussed during the workshop

- Natural hazards (e.g. landslides and floods) was not included in the BN since it is not a slow-onset hazard and thus, beyond the scope of our study.
- Overgrazing is included in the factor soil degradation
- Forest covers is included in the factor soil degradation