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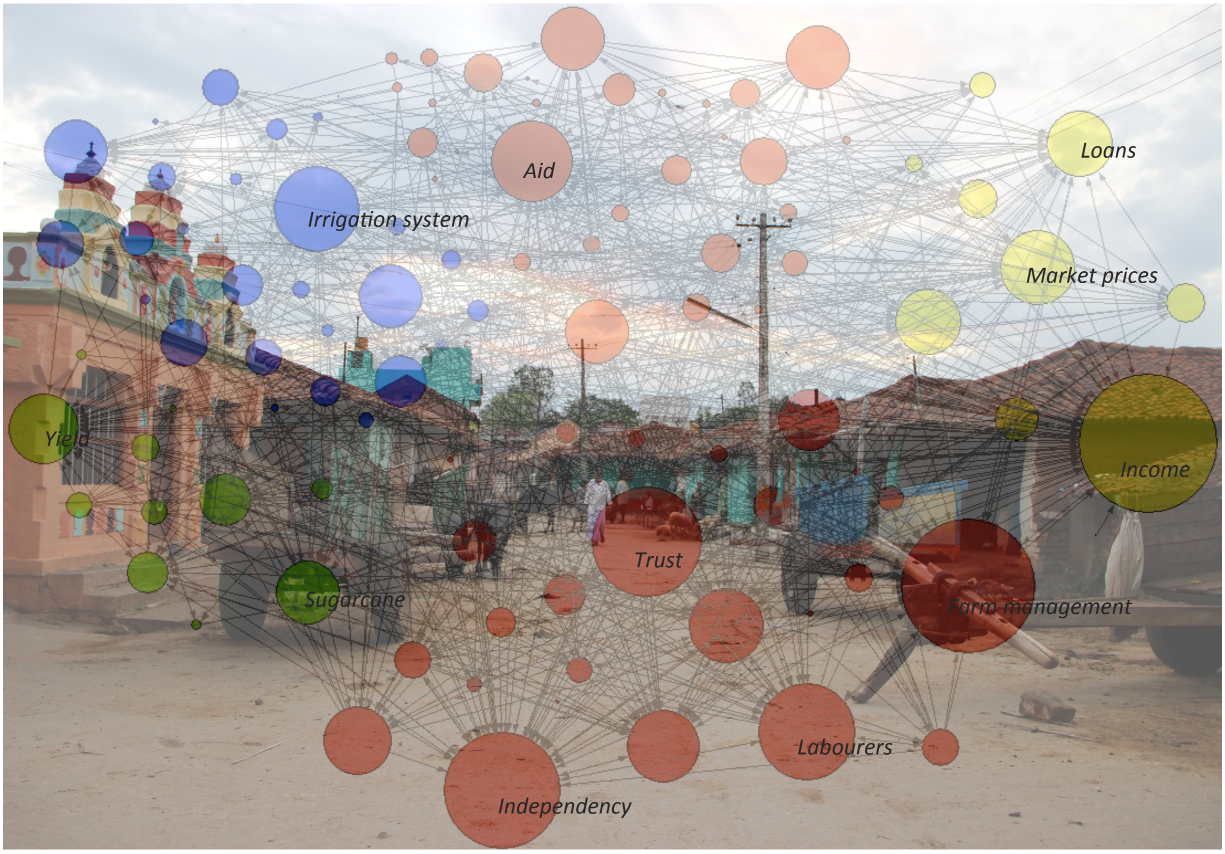
Master Thesis GEO 511

Indigenous knowledge-based identification of adaption barriers regarding a sustainable implementation of a biochar system in Karnataka



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Cover picture

Village portrait of Chandagalu

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Summary

Biochar is a carbon rich compound that is created when biomass is pyrolysed - a process of heating biomass under absence of oxygen. Various studies about biochar as a soil amendment revealed its potential to enhance soil fertility and thus agricultural yield output. Furthermore due to its high recalcitrance it has a slow decay rate and might be a crucial applicable instrument to mitigate climate change.

A biochar system involves all processes and activities concerning the production of biochar and additionally enables bioenergy production during pyrolysis and efficient waste-management, thus remaining agricultural bio-waste can be used as feedstock for biochar production. A biochar system in this sense might be a practicable solution to meet today's and future challenges across agriculture, climate change and energy.

For these reasons, scientific and political stakeholders show high interest in this new technology. Research showed, that especially tropical soils respond positive of biochar applications. Regarding the other benefits of a biochar system - agricultural yield output enhancement, energy production and waste management - an implementation of a biochar system might be particularly interesting for agricultural and development contexts, within tropical regions.

In the context of the interdisciplinary platform "InnoPool" of the University of Zurich, the idea of an implementation of a biochar system into the sugar production circle of Karnataka, South India was launched in February 2012. However for investment decision-makings previous field studies have to be conducted, in order to identify the sustainability of the project. Within the biochar research community mostly biophysical or economic cost-benefit analyses approaches were applied to determine the feasibility of a biochar system implementation so far.

An implementation of a new technology, such as a biochar system, however bears always uncertainties and risks, which might affect socio-ecological system resiliencies and thus individual vulnerabilities. Therefore, for this master thesis project, a social approach was chosen to identify the potential alteration of socio-ecological system resiliencies and individual vulnerabilities regarding a biochar system implementation in Karnataka.

Based on indigenous knowledge of farmers in two villages, located in different agro-climatic regions of Karnataka, system-specific resiliencies and individual vulnerabilities were assessed using a participative and qualitative mixed-method approach to iteratively complement and confirm the assessed data. On the basis of these results, a cognitive mapping approach was applied to model the different socio-ecological systems of the two villages. This enabled to mirror the system-specific resiliencies and individual vulnerabilities of these two villages.

To determine the potential alteration of the systems resiliencies and individual vulnerabilities a small-, and large-scale biochar system was hypothetically implemented in these two context-specific socio-ecological systems. As a result, based on the alteration of resilience and vulnerability, general and specific social, ecological and economic adaption barriers regarding an implementation of a biochar system were possible to identify.

The identification of social, economic and ecological barriers revealed that an implementation of a large-scale biochar system would be less cost-intensive and more profitable, since access to assets, which are crucial for a sustainable implementation of biochar system is predominantly constraint in both villages. An implementation of

a small-scale biochar system on the other hand could have the potential to fundamentally transform the farming-based socio-ecological systems to be less-dependent and socially more equal.

In order to achieve the goal of a potential positive transformation of farming based communities in Karnataka, appropriate strategies must be found to provide access to necessary assets for an implementation of a small-scale biochar system. However, since in cases of a negative outcome, farmers' strategies are limited and strongly dependent on external conditions, it is crucial to simultaneously implement an institutional setting that serves as reliable safety net. For these reasons three superior strategies were suggested: i) enhancement of trust; ii) enhancement of equity; and enhancement of technology suitability, in order to guaranty a sustainable implementation of a biochar system and provide conditions for a potentially positive transformation of agricultural based communities in Karnataka.

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1. Introduction

Global environmental change has priority on international policy agendas and also engages politics and society on the local scale. Leading topic of the recent climate summit 2014 in New York was not without a reason - to “take climate action”. Action- and solution-oriented approaches are mandatory in order to adapt and mitigate global environmental change derived consequences.

Such an action- and solution-oriented approach is provided by a biochar system. Biochar is an organic carbon rich compound that is created when biomass is pyrolysed - a process of heating biomass under absence of oxygen. Several studies in controlled and different experimental conditions such as climate, soil or agricultural management techniques have shown that biochar has the potential to increase agricultural yield. Additionally, mitigation of climate change due to carbon sequestration into soil, waste management as a results of the use of bio-waste as feedstock to produce biochar and energy production during the pyrolysis are other positive expectations of a biochar system (Barrow 2012: 24; Leach 2010: 2; Lehmann and Joseph 2009: 147; Spokas 2011: 973).

Interests in biochar arose with the discovery of anthropogenic black and brown earths or terra preta’s and terra mulatas de Indio in Amazonia. These Amazonian dark and brown earths “occur as patches of a darker colour than surrounding underlying soils” (Barrow 2012: 22). Special about these soils are their three or more times higher soil organic matter content, higher nutrient level and lower acidic pH than their surrounding soils (ibid. 2012: 22). As a consequence these soils are more fertile, which results in a higher yield. Examinations of these soils revealed that the main driver of this observed soil fertility is biochar.

Advanced research on biochar and its influence on quality, respective fertility of soils of different climatic regions, indicate that biochar is especially effective in soils of tropical regions (Mankasingh et al. 2011: 5218). Since tropical soils are highly weathered and exhibit a high rate of soil organic matter turn-over, due to faster mineralization, their soil and plant nutrient content is low and thus likewise their fertility (Lehmann and Joseph 2009: 148; Glaser et al. 2002: as cited in Mankasingh et al. 2011: 6218). Especially with respect to the developing context of most tropical regions, an implementation of a biochar system in these regions is particularly interesting.

An implementation of a biochar system in these regions is supposed to not only improve soils and thus food security, but also offers a chance to diversify the agricultural practices of farmers in a positive way. A biochar system might provide possibilities of local energy production and additional income sources in form of carbon credits due to sequestering of carbon. Furthermore it could substitute, and thus lower farmers’ dependency on inorganic fertilizers (Barrow 2012: 21). For these reasons, stakeholders with different background, such as “NGO’s, research bodies and green activists” worldwide are highly interested in biochar systems (ibid. 2012: 24).

In the context of the interdisciplinary platform “InnoPool” of the University of Zurich, the idea of an implementation of a biochar system in an agricultural development context such as Karnataka, South India was launched in February 2012. Karnataka’s agriculture, as well as the rest of India’s agriculture was formed by the green revolution during the 1960’s and later by globalisation processes. Peasants who produced primarily “to meet the subsistence requirements of him [- or herself] and his [or her] family”, became farmers, who are market-driven and produce cash crop, such as sugarcane (O'Brien et al. 2004[b]: 304; Panini 1999: 2169). The downside of this shifting in farm management practices is an increasing dependency regarding high-yielding inputs, including high quality seeds, "irrigation, chemical fertilizers and pesticides" (O'Brien et al. 2004[b]: 304). As a consequence initial low fertile soils were depleted and fertilizer use and dependency increased even more. An implementation of a biochar system into the sugar production circle in Karnataka could possibly stop this downward spiral and provide a practical technology for rehabilitating degraded land, enhance soils fertility and thus crop yield and simultaneously lower inorganic fertilizer dependency (Barrow 2012: 21; Leach 2010: 2; Lehmann and Joseph 2009: 438).

The basic idea accordingly is to use the remaining biomass or bagasse of sugar and/ or jaggery production to produce biochar and favourable bioenergy products to partially meet the India's demand of energy (Ariza-Montobbio and Lele 2010: 189). Within the biochar research community research about biophysical adaption of biochar or economic cost-benefit analyses approaches were applied to determine the feasibility of a biochar system project, but little research about social aspects regarding an implementation of a biochar system has been done so far (Barrow 2012: 22; Lehmann and Joseph 2009: 362; Spokas 2011: 973). However, an implementation of a new technology requires more than "technical knowhow" or a "quantification of financial impact" (Barrow 2012: 23; Hanmer et al. 1997: as cited in Lehmann 2009: 360). To be sustainable, an implementation also has to consider social aspects.

Social aspects are crucial regarding social acceptance, since, regarding an implementation of a biochar system, "soil nutrient improvements may take time to occur and soil structure changes strong enough to improve plant growth may not occur in one to four growing seasons" (Barrow 2012: 23). Social aspects should also be considered, since a new technology always is affiliated with uncertainty and risks. Implementations of new technologies are necessary, otherwise there would be no progress. However, since the goal of sustainable development "is to eliminate risks to the most vulnerable", potential risks caused by an implementation of new technologies and there consequences on social vulnerability have to be considered (Adger 2006: 276).

Social acceptance and causes of vulnerability are strongly context-related (Adger 1999: 250; Carney 2003: 23). A technology thus that is feasible at one place, is not automatically appropriate at another place (Lehmann and Joseph 2009: 147; Smit and Wandel 2006: 288). Context-specific social, economic and ecological conditions shape and determine social vulnerability and thus consequently the suitability of a new technology (Adger 1999: 250; Lehmann and Joseph 2009: 148; Spokas et al. 2011: 973). Therefore it is crucial to assess local context-specific social, economic and ecological conditions of a system, to identify system-, and individual vulnerabilities and accordingly adaption barriers regarding an implementation of a biochar system (Lehmann and Joseph 2009: 365; Tang et al. 2013: 17). Based on this data, it might be possible to design a technology that creates a value and not a risk for the users (Lehmann and Joseph 2009: 232).

To determine the social feasibility of a biochar system implementation in Karnataka, therefore a local-based study was conducted, in order to answers the following two research questions:

> **What are the general and specific social, economic and ecological adaption barriers regarding a sustainable implementation of a biochar system in Karnataka?**
>
> **What is the significance of these social, economic and ecological adaption barriers regarding a sustainable implementation of a biochar system in Karnataka?**

To identify general and specific adaption barriers a participative assessment of system- and individual vulnerabilities regarding an implementation of a biochar system at two selected villages of different agro-climatic regions was conducted. One village is located within a dry climatic zone, where sugarcane is one of the main crops of cultivation and the other village is located within a wet climatic zone, where paddy is one of the main crops of cultivation. Based on the assessed indigenous knowledge social, economic and ecological adaption barriers were identified, in order to determine their significance regarding a sustainable implementation of a biochar system in Karnataka.

The following chapters of this master thesis are documenting the process of data conduction, analysis and the identification of indigenous-knowledge based adaption barriers regarding an implementation of a biochar system in Karnataka. First of all, a review about the components of a biochar system, the potential benefits, uncertainties and risks is provided. Afterwards, a survey of the main theoretical concept of vulnerability, which is used as basis for the data conduction and analysis, illustrates the diversity of vulnerability assessment methods within social and environmental science. This survey of different assessment methods demonstrates the origin and composition of the underlying theoretical concept.

A chapter about the research area clarifies the selection criteria of the two villages, where the data assessment took place and provides additional background information about the climatic and agricultural differences of the two villages. Further the choice and a critical reflexion of the different research methods, that were applied to assess the systemic and individual vulnerabilities at these two places, is illustrated. Afterwards selected results of the data assessment were documented and analysed and based on the analysis of these results, adaption barriers and their significance for a sustainable biochar implementation in Karnataka were identified and discussed. A final chapter is summarizing these findings and is presenting normative suggestions for a sustainable implementation of a biochar system in Karnataka.

2. Biochar systems: Potential benefits, uncertainties and risks

In order to estimate the outcome of an implementation of a biochar system within a real agricultural context it is necessary to define the elements of a biochar system, its assumed potential benefits, uncertainties and risks. The following four sections illustrate i) the potential benefits of a biochar system, ii) the elements of a biochar system and how an implementation of a biochar system within a real agricultural system might be influenced and influencing the pre-existing biophysical and socio-economic resources. Further an overview of the ongoing political and scientific debate about iii) the uncertainties and iv) the risks of an implementation of a biochar system.

2.1. Potential benefits of a biochar system

Biochar is a carbon-rich organic matter product of slow pyrolysis of biomass (Barrow 2012: 23; Carrier et al. 2012: 24). Pyrolysis is a term that describes the thermal degradation of organic material under the absence of oxygen (Duku et al. 2011; Jeffery et al. 2013: 1; Roberts et al. 2009: 827; Sohi 2010: 49). While the production of biochar has similarities with the production of traditional charcoal its intentional usage is different (Lehmann and Joseph 2009: cited in Jeffery et al. 2013: 1). Charcoal is rather used as energy source such as fuel; whereas biochar is produced for application to soil with the intention to improve soil productivity and to sequester carbon (Lehmann and Rondon 2006: cited in Barrow 2012: 23).

The promises and expectations of a biochar system are high. Table 1 lists the potential agronomic, environmental and socio-economic benefits of a biochar system. Due to the physical and chemical properties of biochar, its application to soil has the potential to improve soil quality and thus soil fertility and crop yield. The physical structure of biochar is highly porous, thus it contains a large surface area (Atkinson 2010: 1). For these reasons biochar has a high water retention capacity and can improve the moisture content in soil (Barrow 2012: 24; Carrier et al. 2012: 31; Leach 2010: 2). Additionally, this structure enables a long-term stabilization of nutrient-rich organic matter by forming aggregates or organo-mineral formations and hence an increase of important plant nutrients in soil (Atkinson et al. 2010: 7; Carrier et al. 2012: 25; Lehmann and Rondon 2006: 518; Lehmann and Joseph 2009: 86ff; Mankasingh et al. 2008: 5218). Otherwise nutrient availability increases by biochar additions to soil caused by functional groups on the surface of biochar, which enhances the potential of biochar to increase soil's cation exchange capacity. Those functional groups are electron donors; hence they have the potential to improve the available quantity of relevant nutrients for plants by retaining and exchanging them (Atkinson et al. 2010: 7; Carrier et al. 2012: 25; Lehmann and Rondon 2006: 528; Lehmann and Joseph 2009: 121f; Mankasingh 2011: 5218). Furthermore biochar is having a high pH-content and soil pH might increases by adding biochar (Atkinson et al. 2010: 7; Barrow 2012: 24; Duku et al. 2011: 3547). Acidic soil might become alkaline and would as well enhance nutrient availability (Carrier et al. 2012: 30; Lehmann and Rondon 2006: 519). All those changes in soil properties improve habitat suitability for soil microorganisms, such as mycorrhizal fungi, bacteria and/ or earthworms (Atkinson et al. 2010: 1; Barrow 2012: 24; Carrier et al. 2012: 31; Lehmann and Joseph 2009: 520; Lehmann 2009: 86). These not only support fixation of nitrogen, which is a limitation factor of plant grow, especially in rice production, but also improve nutrient availability for plants and thus enhance crop productivity (Barrow 2012: 24; Carrier et al. 2012: 27).

Table 1: Properties of biochar and potential benefits of a biochar system (own representation).

Properties of biochar	Potential agronomic benefits		Potential environmental benefits	Potential socio-economic benefits
	Improvement of soil quality	Improvement of crop productivity		
Highly porous structure [1] Large specific surface area [1, 4] High chemical and microbial stability/ Slow decay rate [1, 9, 10] High cation exchange capacity [1,] High pH [1, 9]	Improvement of water holding capacity and/ or soil moisture retention [2, 4, 7] Stabilization of organic matter/ Slower nutrient release from added organic matter [1, 4, 9, 10] Improvement of soil nutrient retention and cation exchange capacity/ Binding of important nutritive micro (Cu, Zn, Fe, Mn) and macro cations and anions (P, K, N, Ca) [1, 4, 8, 9. 10] Increase of soil pH [1, 2, 5, 8] Assimilation of beneficial soil micro- and macro-organism (mycorrhizal fungi, bacteria, earthworms) causing higher nutrient availability for plants [1, 2, 4, 8, 9] Support of nitrogen fixation/ Reduction of nitrate leaching [2, 4]	Increase of fertility (especially in tropical soils)/ Yield increase (depending on the added quality and/ or quantity of biochar) [1, 2, 5, 8, 10] Increase of bioavailability and plant uptake of key nutrients (particularly when in the presence of additionally added nutrients) [1, 5] Retention of plant nutrients, notably retention of N on permeable soils under rainy conditions [2]	Storage of organic carbon in soil/ Reduction of atmospheric carbon/ Mitigate climate change [2, 5, 10, 11] Binding of phosphate and nitrate and reduction of ammonium leaching/ Reduction of streams and groundwater pollution [1, 2, 5] Absorption of contaminants from soils [e] Reduction of greenhouse gas emissions in agriculture (nitrous oxide (N_2O) and methane (CH_4)) [1, 2, 5, 9, 11]	Reduction of lime applications [5, 6] Increase of income [5, 7] Increase of food security [7] Reduction of irrigation system dependences and/ or climate change risks/ uncertainties (floods/ droughts), caused by improvement of water holding capacity [2] Opportunity to benefit from carbon offset market/ Carbon trading [2, 5] Reduction of inorganic fertilizer, manure and/ or compost/ Reduction of farmer's dependence on input suppliers [2, 7] Usage of (agricultural) unused waste/ residues [2, 5, 11] Bioenergy production (syngas (heat/ electricity), bio-oil) [2, 3, 7, 11]

References: Atkinson et al. (2010) [1]; Barrow (2012) [2]; Brick and Wisconsin (2010) [3]; Carrier et al. (2012) [4]; Duku et al. (2011) [5]; Galinato et al. (2010) [6]; Leach (2010) [7]; Lehmann and Rondon (2006) [8]; Lehmann and Joseph (2009) [9]; Mankasingh et al. (2011) [10]; Shackley et al. (2011) [11]

Consequently soil quality is optimized by the addition of biochar, thus yield might increases and therefore income and food security (Duku et al. 2011: 3547; Leach 2010: 26) of a farmer. Likewise the dependency on irrigation systems caused by the improvement of the water holding capacity might be mitigated (Barrow 2012: 24) and lime applications to soil by farmers might be possible to reduce due to increasing pH caused by biochar application (Duku et al 2011: 3547; Galinato et al. 2010: 5). Manure, compost and inorganic fertilizer additions might be partially substituted by biochar and hence their negative impact on the environment might be possible to diminish. Manure, compost and inorganic fertilizer are ammonia, phosphate and/ or nitrate sources and due to the properties of biochar, those plant nutrients can be absorbed and leaching might be hindered as it would be the same with other environmentally harming contaminants (Shackley et al. 2011: 335). Ammonia, phosphate and nitrate input not only to soil, but as well to groundwater and/ or stream pollution could be reduced (Atkinson et al. 2010: 2; Barrow 2012: 26; Duku et al. 2011: 3549). Accordingly farmers are able to reduce their farm management costs and their dependency on soil input producers (Barrow 2012: 24; Leach 2010: 10). Farmer's income might moreover increase due to potential of carbon trading on international carbon markets caused by incorporation of biochar to soil (Barrow 2012: 24; Duku et al. 2010: 3547; Leach 2010: 19; Mankasingh et al. 2011: 11; Shackley et al. 2011: 335). This is the case, due to the high recalcitrance of biochar, which is caused by the pyrolysis of biomass, turning its carbon content into aromatic and hence stable structures (Atkinson et al. 2010: 1; Lehmann and Joseph 2009: 192; Mankasingh et al. 2011: 5218). This offers the chance to sequester carbon in soil and mitigate the climate change.

Other studies on biochar as well have shown less greenhouse gas emissions (N_20, CH_4) of soil as a result of biochar addition as it is the matter with compost addition (Atkinson et al. 2010: 1; Barrow 2012: 24; Duku et al. 2011: 3548; Lehmann and Joseph 2009: 148; Shackley et al. 2011: 335). Also divers unused agricultural waste or residues can be recycled, by using them as a biomass source for the production of biochar (Barrow 2012: 24; Duku et al. 2012: 3540; Shackley et al. 2011: 335) and as well bioenergy, such as syngas and/ or bio-oil can be produced by the process of pyrolising (Barrow 2012: 24; Brick and Wisconsin 2010: 1; Leach 2010: 2; Shackley et al. 2011: 335). In summary the benefits of biochar systems include (i) soil fertility enhancement and hence yield and income increase; (ii) pollutant immobilization and groundwater and/ or stream pollution; (iii) carbon sequestration; (iv) waste disposal and v) biofuel/ bioenergy production (McHenry 2008: 1; Jeffery et al. 2013: 1; Lehmann and Joseph 2009: 148).

2.2. Components of biochar system

The product biochar and thereby its potential benefits to agriculture, climate change and energy (Leach 2010: 2) does not stand on its own. Its production and application to soil has "to be viewed from a system perspective" in order to consider likewise socio-economic and environmental costs and trade-offs, hence potential constraints, and to understand fully the agronomic, environmental and socio-economic net-benefits (Lehmann and Joseph 2009: 147). For these reasons the processes of production and application of biochar and its associated activities have to be understood.

Processes of production and application of biochar involves the following steps: i) biomass has to be produced and collected, transported to the pyrolysis facility, where it is prepared for pyrolysis, hence reduced in size and dried, ii) by pyrolysis the biomass is transformed to biochar and bio-energy products, iii) biochar as a soil amendment is transported to the farm and applied to the field (Roberts et al. 2010: 828; Sohi et al. 2014: 3). Accordingly a biochar system consists of three phases (i) biomass phase and/ or feedstock production, (ii) conversion phase and/ or pyrolysis, (iii) use phase and/ or application (Brick and Wisconsin 2010: 2; Shackley et al. 2011: 336; Sohi et al. 2014: 3). In a narrower sense the processes of production and application of biochar determine the components, respectively phases and hence the associated activities of a biochar system. However in a broader sense each phase of a biochar system is constraint by pre-existing and existing biophysical and socio-economical resources of an agricultural production system, but also alters these pre-existing and existing resources (Sohi et al. 2014: 1, Lehmann and Joseph 2009: 149; McGreeny and Shibata 2010: 21). In the following section based on literature research an illustration is given of how a biochar system is constraint by biophysical and socioeconomic resources of a small-scale farmer and how it potentiality alters his socio-ecological environment (Figure 1).

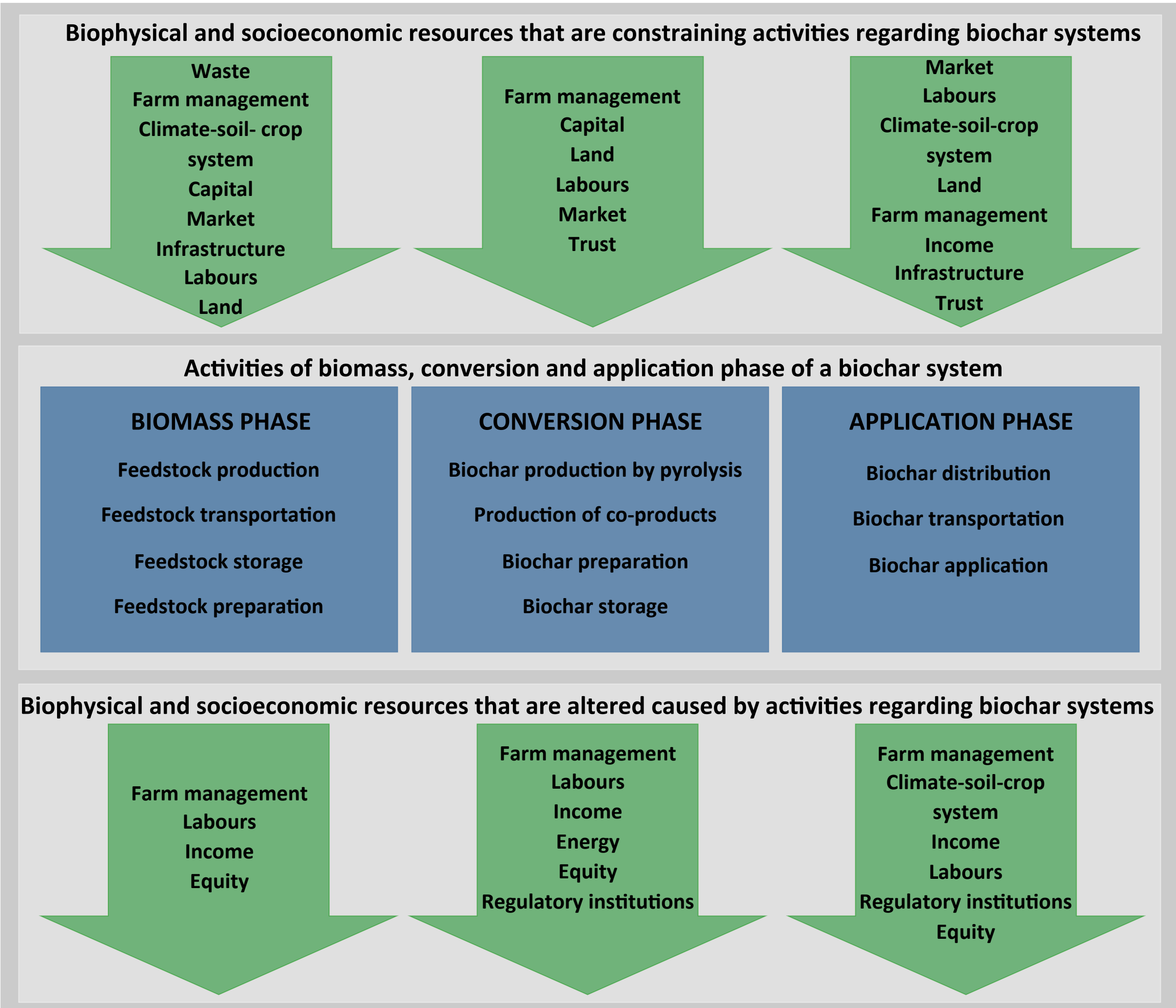

Figure 1: Biophysical and socioeconomic resources that are constraining biochar system associated activities of biomass, conversion and application phase and potentially altering biophysical and socioeconomic resources by an implementation of a biochar system. (References: Abiven et al. 2014; Barrow 2012; Brick and Wisconsin 2010; Duku et al. 2011; Leach 2010; Lehman and Joseph 2009; McGreeny and Shibata 2010; McHenry 2008; Mekuria et al. 2013; Roberts et al. 2009; Shackely et al. 2013; Sohi et al. 2014) (own representation).

The biomass phase involves activities concerning feedstock production, transportation, storing and preparation (Sohi et al. 2014: 3). Relevant activities regarding the biomass phase primarily depend on the kind of biomass, which is used as feedstock to produce biochar by pyrolysis (Sohi et al. 2014: 3) and its "practical and economic feasibility of […] acquisition" (Abiven et al. 2014: 326; Lehmann and Joseph 2009: 149; Sohi et al. 2014: 3). Biomass hereby is classified into virgin and non-virgin biomass (Shackley et al. 2011: 336; Sohi et al. 2014: 5). Virgin biomass derives from whole (or parts of) plants and trees, or from the processing of biomass, where this does not involve chemical or biological transformation, amendment or treatment (Shackley et al. 2011: 336). Non-virgin biomass is biomass that has been chemical or biological transformed before using as feedstock source for biochar production (Shackley et al. 2011: 336; Sohi et al. 2011: 5).

Whereat non-virgin biomass and mechanical transformed virgin biomass in most cases are produced and available from processing industries of agricultural products, virgin biomass, such as whole parts of plants and trees or any agricultural *waste*, such as livestock or plant residues after harvesting could potentially be provided by a local farmer. In both cases pre-existing management procedures and logistical factors are constraining the availability of biomass. The decision of a small-scale farmer respectively to supply suitable biomass for biochar production hence are defined by *farm management* decisions that are themselves strongly influenced by biophysical factors such as *climate* and *soil* type that determine which *crop* is possible to grow (Roberts et al. 2009: 828; Sohi et al. 2014: 1), but also by socioeconomic factors such as available *capital*, *market* conditions of crops and agricultural inputs (fertilizer, manure, etc.), *land* ownership, *labours* costs and their availability (Sohi et al. 2014: 1; Shackley et al 2011: 341; Lehmann and Joseph 2009: 148f). Further the facility and costs of *transportation* of biomass, which is shaped by the *infrastructure*, such as roads and existing local industries, is determining the kind and availability of biomass that is used as feedstock source to produce biochar (Lehmann and Joseph 2009: 148f). The amount of transportation costs hereby is varying, whether biochar is locally produced or as a side-product of agricultural industry (ibid. 2009: 152f; Sohi et al. 2014: 3). Once feedstock is collected, it has to get prepared and stored. Consequently these additional activities have as well to be positively adopted by pre-existing *farm management* or industrial production activities, whereby in some cases additional *labour* force is needed (Sohi et al. 2014: 14).

Alternatively, the decision to produce biochar feedstock consequently alters *farming* activities and its *management*. As well pressure on *labour*-availability might increase caused by potentially labour-intensive biomass production, transportation, preparation and storage needs additional. Farmer's *income* might change positively regarding additional income sources due to biochar feedstock supply but also might change negatively due to additional labour and transportation costs. However, not every small-scale farmer might be able to provide biomass for biochar production. Which particular farmer might profit the most on the associated activities of biomass phase depends on the availability and access of the resources that are determining the feedstock supply. Farmers with less land or without any land ownership, and/ or farming-based households, where no sufficient funds are available to pay the wages for labours and the arising transportation costs (Shackley et al. 2011: 354), are not able to produce feedstock for biochar production. Consequently biomass phase might potentially alter pre-existing levels of social *equity* (Sohi 2014: 13).

The conversion phase involves activities concerning the process of biochar production by pyrolysis, preparation and storage of biochar as a soil amendment and the production of by-products such as syngas and bio-oil by the process of pyrolising (Barrow 2012: 24; Brick and Wisconsin 2010: 1; Leach 2010: 2; Shackley et al. 2011: 335; Sohi et al. 2011: 5). This involves primarily sufficient capacity for non-farming activities that is as well constraint by pre-existing *farm management* activities (Sohi et al. 2014: 1). Otherwise sufficient financial *capital* for the initial and working costs of production, including machine, machine maintenance and labour costs are constraining a successful realisation of the conversion phase (Abiven et al. 2014: 326; Brick and Wisconsin 2010: 6; Roberts et al. 2009: 829; Shackley et al. 2011: 341). Likewise relevant are additional *land* rights and therefore available land or place to build a pyrolysis unit and store and prepare biochar (Sohi et al. 2014: 1), plus availability of *labours* and a *market* where biochar as soil amendment and potential bioenergy products are tradable (Lehmann and Joseph 2009: 149). Market establishment is strongly tied to social acceptance and hence *trust* to the technology and the end products (Mekuria et al. 2013: 1). Otherwise investment of farmers might be cautious.

A potential biochar production within a village, consequently leads to a shift in *farm management* and as well to an increase of *labour* demand (Sohi et al. 2014: 14). But if socio-economic demand is achieved, biochar production might have the potential to increase producer's *income* (McHenry 2008: 5). Additionally *energy* might be possible to produce, thus energy need might be reduced or energy might be sold to gain additional profit (McHenry 2008: 5). Nevertheless potential gains of profit of certain farmers who own the capital and resources to set-up a pyrolysis unit, might reinforce social *equity* gaps (Sohi 2014: 13). To ensure good quality biochar products on the market, *regulatory institutions* might have to be established in order to monitor the quality of the outputs of pyrolysis (Duku et al. 2011: 3549; Shackley et al. 2011: 341).

The use phase mainly involves activities of biochar distribution, transportation and application as soil amendment (Sohi et al. 2014: 5; Shackley et al. 2011: 341) and hence is strongly tied to the existence or establishment of biochar *markets*, whereby the utility of the product and consequently the *trust* of the end-users of its promoted utility is defining farmers demand (Mekuria et al. 2013: 1). The utility hereby is determined by the *climate-soil-crop system*, by *land* ownership and the local and/ or individual *farm management* (Sohi et al. 2014: 8) and by the affordability of the product, which is compromised by the market price of the product and the *income* of the farmer. To use biochar on the field it has to be transported from the site of production to the side of usage. Transportation costs again will influence farmer's income, dependent on the available *infrastructure* above all roads. To incorporate biochar in the soil again *labours* are needed, hence labour availability and costs might constrain the utility and application of biochar (Mekuria et al. 2013: 9; Sohi 2014: 14). Considering the side effect of sequestration of carbon into soil, access to carbon *market* has to be ensured, whether that is an establishing of new markets for carbon or the feasibility for farmers to have access to such markets.

Likewise as farm management strategies constrain potential usage of biochar, an application of biochar to soil alters their *farm management* strategies (Sohi et al. 2014: 9). An application might change their *climate-soil-crop system* hence the diversity of crop might be increased, because the fertility of soil is improved and climate change might be mitigated (McHenry 2008: 6). This might increase their *income* but also is associated with additional costs, such as *labours* or transportation costs for the realisation of application procedures. Social *equity* hereby is moreover affected, thus not every farmer is having the financial sources to buy and apply biochar and be able to make profit of a higher yield (Sohi et al. 2014: 13). *Regulatory institutions* might have to be established as well, to ensure sustainable use of biochar to be able to control misuse (Shackley et al. 2011: 341) and hence protect soil, which is the livelihood foundation of farmers.

2.3. Identification of biochar systems uncertainties

The promoted benefits of biochar systems are high. However an implementation of a biochar system within a socio-ecological environment is as well associated with costs and a potential of shifting pre-existing and existing components and/ or resources. Accordingly with respect to an implementation of a biochar system into a real agricultural context "not just the quantification [and effectiveness] of the financial impact of biochar technology, but also the broader social, cultural, political and environmental impacts" have to be considered (Hanmer et al. 1997: as cited in Lehmann and Joseph 2009: 360). Future predictions of success or failure of biochar systems might be facilitated if potential benefits, costs and system influences would be certain, but as the matter of fact biochar system impacts on social-economic and ecologic environments remain uncertain. Table 2 lists several linked environmental, methodical, economic and social uncertainties of biochar systems, which are described closely in the following section.

The desired effect of biochar as a soil amendment is primarily dependent on the dynamics and responses of the *climate-soil-crop system* (Brick and Wisconsin 2010: 2). Various studies in different climate-soil-crop combinations have been conducted and in most cases results were highly heterogeneous from highly positive to even negative crop response (Brick and Wisconsin 2010: 9; Galinato et al. 2010: 3; Leach 2010: 31). So far no attribution of a significant general factor that determines a successful application of biochar for different climate-soil-crop systems in order to increase the quality of soil has been possible to determine (Brick and Wisconsin 2010: 3; Jeffery et al. 2013: 4; Leach 2010: 30). Interestingly, most of the successful studies have been conducted under controlled conditions and were located in the semi- and tropical regions (Leach 2010: 30), where the "greatest and most consistent yields are found on highly degraded soils" (Roberts et al. 2009: 829). Results of studies in regions with continental climate regarding the increase in soil fertility by biochar addition were less numerous and often modest; hence most studies have taken place in already well-fertilized soils (Jeffery et al. 2011: 186). For these reasons prognoses about regions for real agronomic systems and for regions with continental climate are uncertain at the present (Leach 2010: 30). Brick and Wisconsin (2010: 3) and others (Jeffery et al. 2013: 9) therefore recommend the establishment of a classifying scheme for different climate-soil-crop systems and their response on different biochar, because as the climate-soil-crop system is highly divers, biochar and its characteristics are as well very heterogeneous. These uncertainties remain especially important considering the high recalcitrance of biochar. Biochar might have a long *residence time* in soil, depended as well on the interplay between climate-soil-crop system and the characteristics of biochar, hence potential negative effects caused by misfitting of biochar and climate-crop-soil systems combinations might not be simply to make reversible (Duku et al. 2011: 3540; Barrow 2012: 23).

Responses of a climate-crop-soil system depend as mentioned previous on the *suitability of the properties of biochar* (Thies and Rilling 2009: as cited in Leach 2010: 39). Differences of the characteristics of biochar vary accordingly to the choice of the initial feedstock and its properties (Brick and Wisconsin 2010: 2; Duku et al. 2011: 3540; Jeffery et al. 2013: 9; McHenry 2008: 3; Yao et al. 2012: 1467); therefore not every "agricultural waste is suitable for biochar production" (McHenry 2008: 3; Jeffery et al. 2013: 6). Simultaneously the *suitability of biomass* as feedstock for biochar" production is not only subject of the composition of the feedstock, such as nutrient content and stability (Jeffery et al. 2013: 5), but also economic and logistical factors

Table 2: Environmental, methodical, economic and social uncertainties of biochar systems (own representation).

Uncertainties			
Environmental	**Methodical**	**Economic**	**Social**
Soil-climate-crop system response [2, 4, 5, 7] Recalcitrance/ Residence time of biochar and hence long term effects on soil [3] Suitability of biochar properties (Pyrolysis conditions (temperature, pressure, slow-/ fast pyrolysis) and feedstock characteristics define the physical (composition, particle and pore size distribution) and chemical (CEC, pH) properties of biochar) [2, 3, 5, 7, 10, 15] Suitability of biomass as feedstock (depends on the nature, chemical composition of the feedstock, as well as environmental and logistical factors) [2, 3, 5, 10] Net carbon benefit amount (varies dependent on conversion method, feedstock, climate-soil-crop-system and wind and rain erosion;) [1, 2, 4, 5, 10, 13] Amount of carbon emissions while production and application (harvesting, transporting, pyrolizing, ploughing) [1, 2]	Pyrolysis conditions [2, 3, 4, 5, 10, 13] Application method (rate and amount of application, incorporation method into soil and/ or additional use of fertilizer or manure) [2, 8, 10] Size of pyrolysis unit [2, 9, 10, 12, 14]	Production (feedstock, pyroliser, transport, storage, labour, monitoring) and consumer (labour, transportation, application, monitoring) costs [2, 10, 13, 14] Availability and access to (biochar) market and carbon market [1, 2, 4, 6, 9, 10]	Suitability of local farm management practices [7] Social, political or cultural barriers (motivation, farmer adaption, education, reputation, trust) [2, 9, 10, 11]

References: Biofuelwatch (2011) [1]; Brick and Wisconsin (2010) [2]; Duku et al. (2011) [3]; Galinato et al. (2010) [4]; Jeffery et al. (2013) [5]; Jones et al. 2013 [6] ; Leach (2010) [7]; Lehmann and Rodon 2006 [8]; McGreevy and Shibata (2010) [9]; McHenry (2008) [10]; Mekuria et al. (2013) [11]; De Miranda et al. (2012) [12]; Roberts et al. (2009) [13]; Shackley et al. (2011) [14]; Yao et al. (2012) [15]

have to be considered (Duku et al. 2011: 3540). Obviously an appropriate feedstock due to its preferential characteristics is consequentially not easy to acquire (Jeffery et al. 2013: 5).

Otherwise *pyrolysis conditions* define if a biomass is suitable as feedstock for biochar (Duku et al. 2011: 3540). Temperature, pressure and slow or fast pyrolysis define the end-product and its properties (Brick and Wisconsin 2010: 2; Duku et al. 2011: 3540; Jeffery et al. 2013: 9; McHenry 2008: 3). PH and cation exchange capacity are a function of temperature, whereas highest cation exchange capacity has been found at 700° to 800° C (Jeffery et al. 2013: 5; Lehmann 2007: as cited in McHenry 2008: 4). Likewise physical properties of biochar that influence the water holding capacity, nutrient retention capacity and/ or microbial habitat possibility are variable accordingly to the pyrolysis temperature. For high surface areas also higher temperature are favourable, hence temperatures under 400°C are resulting in low surface areas and "might be not useful as an agricultural soil improver" (Lehmann 2007: as cited in McHenry 2008: 3). Pyrolysis conditions and the choice of feedstock also determine the carbon content and stability of biochar and hence the amount of carbon that can be sequestered into soil. However results vary, according to Collins (2008: as cited in Galinato et al. 2010: 6) the ranges are between 61% and 80%, whereat the lower the temperature, the higher the carbon recovery (Lehmann et al. 2006: as cited in McHenry 2008: 2). Otherwise the speed of pyrolysis determines the stability, thus slow pyrolysis produces biochar that is more stable than fast pyrolysis (Roberts et al. 2009: 829). Hence slow pyrolysis is favourable and best trade-off according to carbon recovery, cation exchange capacity and surface area are pyrolysis temperatures around 500° C, as Lehmann (2007: as cited in McHenry 2008: 4) stated.

However the final *net amount of carbon* that can be stored effectively into soil varies again on the response of the climate-soil-crop system (Spokas 2010: as cited in Jeffery et al 2013: 3; Zimmermann 2010: as cited in Jeffery et al. 2013: 3). Some biochar used in some particular soil-crop-system might stimulate soil microbes more than desirable, so that existing soil organic carbon turns into atmospheric CO_2, a process called priming effect (Biofuelwatch 2011: 4; Maestrini et al. 2014). However it is still unknown why some soil organic matter "persists for millennia whereas other decomposes readily" (Biofuelwatch 2011: 4). In a case where biochar decomposes easily and stimulates microbial activity, biochar input into soil hence is not mitigating climate change; it is moreover reinforcing it. Likewise water and/ or wind erosion might diminish the amount of carbon effectively stored in soil (ibid. 2011: 4). In questioning the net amount of carbon that can be sequestered into soil the NGO Biofuelwatch (2011: 4) and Brick and Wisconsin (2010: 3) are going even further. They state that likewise carbon emissions while harvesting the feedstock, transporting feedstock and biochar, pyrolysing and application of feedstock to soil have to be considered (ibid. 2011: 4). Those aspects vary accordingly to the specific contexts of the agricultural systems and hence are depending on geographic aspects, such as the distance of the place of feedstock production and collection, the place of producing biochar, the place of application and accordingly to the transport-related emissions, which consequentially reduce the "overall carbon benefit of the biochar project" (Brick and Wisconsin 2010: 3).

The choice of *application methods* is essential to the net amount of carbon stored into soil (Brick and Wisconsin 2010: 9), as well as for the impact on the soil-climate-crop system. Blackwell et al. (2008: as cited in McHenry 2008: 3) mention different methods of applying biochar to soil. These are: uniform mixing, forming deep layers of biochar under the surface, deep banding, application while seeding, topdressing, aerial delivery, specific application to ailing vegetation at the root, ecological delivery via animal excreta or tilling. Each of those methods has its advantages and disadvantages regarding the turnover rate of biochar and hence the effectiveness of sequestering carbon or regarding the effects on the soil-climate-crop system. Some methods might disturb soil structure by breaking up aggregates or promoting loss of native soil organic matter; others increase the probability of wind or water erosion of the biochar adjustments; or others might disturb organism (Jeffery et al. 2013: 7; McHenry 2008: 3). Unclear as well is the right amount and rate of application. Whereby, low levels and low application rates of biochar resulted in better but still highly variable yield improvements - results range between 20 to 220% - high application rates resulted in declining yields (Lehmann and Rondon 2006: 518). Declining yields caused by high application rates of biochar hereby were explained as effects of nitrogen limitations, due to enhancement of microbial activity (ibid. 2006: 518). Other methodical uncertainties remain on the effect of additional use of fertilizer or manure (McHenry 2008: 4). In some studies additional input of fertilizer increased the yield even more than using only biochar, others showed no significant effect of application whether of solely biochar or with biochar and fertilizer (Jeffery et al. 2011: 180).

Other methodical uncertainty persists regarding the *size of the pyrolysis* unit. Biochar can be produced whether on a large- or industrial-scale or on village- or small-scale basis. Whereat in small-scale biochar systems biomass acquisition, biochar production and biochar application would be concentrated at one place, large-scale biochar systems require more logistical efforts (McHenry 2008: 5). However, traditional methods that would be used in small-scale biochar systems, such as “pit kilns” or “earth-mound kilns” (De Miranda et al. 2013: 172) are having a higher emission level, are less efficient and less controllable than larger, modern systems, such as “micro-wave kilns”, “container kilns” or “continuous kilns” (De Miranda et al. 2013: 172). Hence monitoring costs would be higher for small-scale production, than for large-scale production (Brick and Wisconsin 2010: iv). Most of large-scale systems would as well provide the opportunity to coproduce bioenergy products, such as bio-oil and syngas (Brick and Wisconsin 2010: 1), which is at present not effectively with small pyrolysis units. For bio-oil fast pyrolysis and for syngas high temperatures are necessary (Jeffery et al. 2013: 5). Contrary for carbon-stable biochar production slow pyrolysis and moderate temperatures are favourable. A holder of a pyrolysis unit has to decide whether to invest in bioenergy products or in biochar, thus a decision to focus on the production of biochar results in a reduction on energy output of ca. 30% (Gaunt and Lehmann 2008: as cited in Jeffery et al. 2013: 5), whereat a focus on production of bioenergy products reduces high quality biochar outputs. These outlines question a combined realization of all the propagated benefits of a biochar system within a real agronomic system, thus context-specific trade-offs have to be made (Jeffery et al. 2013: 2).

Regarding the implementation uncertainties for small- or large-scale producers are further *production costs* (Shackley et al. 2011: 353), such as feedstock, pyrolysis unit and its maintenance, labour and transportation (Roberts et al. 2009: 827) and production gains (McGreevy and Shibata 2010: 19). Consequently, potential *consumer costs* regarding the biochar acquisition and application on the field, such as transportation and labour have to be considered, thus their willingness to pay for biochar influences the income and profitability of the producer. But estimations about production and application costs remain unsecure, because whether “biochar market nor carbon market” have been successful established (Brick and Wisconsin 2010: 1). Only for the energy output markets are available, hence their prices and costs are possible to acquire and estimate (ibid. 2010: 1). Galinato et al. (2010: 13) suppose that biochar might only be profitable if “market price is low enough, (so that a farmer will earn a profit after applying biochar to the crop field) and/ or a carbon offset market (that recognises the avoided emissions and carbon sequestration due to the application of biochar to soil) exists”. However an establishment of a market for biochar and as well of a carbon market for carbon sequestration through biochar application first have to be established. Carbon market as such exists, but so far “based sinks”, such as soils, are excluded in carbon trading until at least 2020 (Biofuelwatch 2011: 6). Likewise prices of carbon market are highly volatile, ranging for instance from 1 USD to 7.40 USD per metric ton of CO_2 in 2008 (CCX 2008: as cited in Galinato et al. 2010: 7; Jones et al. 2013: 7). Before an implementation access to carbon markets and "enduring prices" have to be realised (McHenry 2008: 6).

On the one side a successful implementation depends on assured profits for the producer and consumer, otherwise no one is willing to invest. On the other side new technologies or agricultural practices need to fit into existing farming livelihoods and "farm management practices". Mekuria et al. (2013: 1) mention that "environmental sustainable and technical feasibility of technologies is a necessary, but not sufficient condition for agricultural technology adaption". But at the present research does not cover possible impacts on farmers' livelihoods and farming practices (Leach 2010: 34). Economic, social and cultural barriers, such as motivation, education, reputation or trust (McGreevy and Shibata 2010: 15f) have to be understood first, in order to predict the limits of the adaption of a biochar technology (Woolfe et al. 2010: as cited in Brick and Wisconsin 2010: 11).

2.4. Identification of biochar systems risks

The risks of biochar systems are strongly coupled to the uncertainties concerning the methods, and the environmental, economically and social impacts. In the following section for each of the three phases of a biochar system potential risks will be exemplified.

An uncertainty that involves all aspects whether environmentally, methodically, economically or socially is the requirement of feedstock for biochar and bioenergy production. With respect to the biomass phase where feedstock production and collection are the major driver of changes in existing agricultural production systems, explicit production of feedstock for biochar systems could lead to significant land-use changes and emissions caused by transportation and collection, if biochar systems might be too successful (Brick and Wisconsin 2010: 11; McGreevy and Shibata 2010: 20). Yoder et al. (2011: 1852) sees hereby the risk of the conversion phase that biochar systems, as they are potential providers of energy as well, could lead to an unsustainable production of feedstock. The possibility to produce bio-energy products, such as biofuels and syngas using the pyrolyser, questions an implementation into a real agricultural context, especially where energy source and demand are not coinciding and prices for bio-energy products are higher than biochar prices (Yoder et al. 2011: 1852). The focus might be shifted from biochar production to bioenergy production and land might rather be used to grow profitable crop for bio-energy production, whether to cultivate the land for food crops and hence compromise food security (Tilmann et al. 2009: as cited in Jeffery et al. 2013: 4; Borras 2010: as cited in Leach 2010: 12). In the extreme case this would lead to monoculture, habitat and biodiversity loss, soil degradation, deforestation and potential land grabbing and would have a significant impact on the natural as on the socio-economic environment (Biofuelwatch 2011: 3; Brick and Wisconsin 2010: 11; Jeffery et al. 2013: 5; Leach 2010: 12). Otherwise, if agricultural waste is used to produce biochar, relevant bio-waste or manure might not return to the land. Important soil organic matter would be removed from the soil, which could lead to depletion, if local farm management practices are not concerned (Brick and Wisconsin 2010: 11; Leach 2010: 34).

Table 3: Potential hazards within biomass, conversion and application phase caused by biochar systems (own representation).

	Potential hazards	
Biomass phase	**Conversion phase**	**Application phase**
Land use conversion emissions for primary biomass [3]	Focus on supplemental energy production [3, 4, 6, 7]	Fugitive loss of biochar during transport and application [3, 6]
Collection and transport emissions [3]	Technological/ pyrolysis failures [6]	Soil carbon loss due to biochar incorporation [3]
Land grabbing [2, 5]	Greenhouse gas emissions [6]	Priming effect [2, 4]
Food insecurity [5]	Particulate air emissions (especially for small units) [3, 6]	Incorporation of contaminants into the soil [4]
Monoculture [2]	Local human health problems [3, 6]	Phytotoxic effects [3, 4]
Habitat and biodiversity loss [3]	Social conflicts [1, 5]	Toxicity effects on soil and groundwater [5]
Soil degradation and deforestation [2, 5, 6]		Climate forcing effect, human health effect [3]
Diversion of crop residues from soils/ Removing of soil organic matter [3]		Decrease of albedo [2]
Non-availability of bio-waste for farm management [5]		Social conflicts [1, 5]
Social conflicts [1, 5]		

References: Ariza-Montobbio and Lele (2010) [1]; Biofuelwatch (2011) [2]; Brick and Wisconsin (2010) [3]; Jeffery et al. (2013) [4]; Leach (2010) [5]; McHenry (2008) [6]; Yoder et al. (2011) [7]

Within the conversion phase not only the risk of misuse of the pyrolysis unit for primarily bioenergy production is a considerable risk, potential emissions of greenhouse gases, such as methane particulate air emissions and as a consequence human health issues might occur as well (Brick and Wisconsin 2010: 11; Bailis 2009: as cited in De Miranda et al. 2013: 174; Taccini 2010: as cited in De Miranda et al. 2012: 174). Hence if no clean pyrolysis technologies are available, local health effects diminish the success of a biochar system and the benefits regarding climate change mitigation (Lehmann et al. 2006: as cited in McHenry 2008: 2). (Sparrevik et al. 2013: as cited in Jeffery et al. 2013: 7). Risks regarding human health and climate might as well occur during application *phase*. Brick and Wisconsin (2010: 11) and Biofuelwatch (2011: 5) mentions hereby "fugitive loss of biochar during transport and application", that could have an impact on human health or further "soil carbon loss due to biochar incorporation" and "decrease of albedo" that would limit the net benefits of carbon sequestration. Another aspect that might diminish the benefits of biochar is the occurrence of priming of soil organic matter, hence an increase of microbial activity and thus an increased decomposition of soil organic matter and a potential fostering of climate change in long term (Biofuelwatch 2011: 4; Cross and Sohi 2011: as cited in Jeffery et al. 2013: 1; Zimmermann et al. 2011: as cited in Jeffery et al. 2013: 1). Shorter-term environmental risks might be the incorporation of unwanted contaminants into soil and groundwater. Given that the properties of biochar are divers, depending on feedstock and pyrolysis conditions, unwanted contaminants that might even have phytotoxic effects could harm soil and/ or groundwater (Gell et al. 2011: as cited in Jeffery et al. 2013: 4; Lima et al. 2005: as cited in McHenry 2008: 3). Those uncertainties points to the risk, that the potential gains of an application of biochar to soil might "turn into losses over the longer term", due to the fact that biochar is highly stable and "negative effects can endure in soil, potentially for thousands of years", as Jeffery et al. (2013: 1) mentions.

The exemplified potential benefits, uncertainties and risks of a biochar system are polarizing: the benefits seem to have the potential to contribute to a solution of today's "pressing challenges across agriculture, climate change and energy" (Leach 2010: 2), but the potential negative effects are pointing rather to a prohibition of any implementations into real agricultural contexts (Smolker 2010: as cited in Leach 2010: 33). Examples of other implementations of new agricultural techniques have shown that if in any case important relevant livelihood resources of farmers were set under pressure, potential social conflicts might occur (Ariza-Montobbio and Lele 2010: 189). However a biochar system varies highly within its components and likewise divers is the impact on different climate-soil-crop and agricultural systems. Hence, uniform explanations of causes and influences are not possible. Before any concrete implementation of a biochar system, "further experimental research [on site] with regard to the long-term effects of biochar on soil functions, as well as on the behaviour and failure in different soil types and under different management practices" have to be conducted (Leach 2010: 31). Likewise socio-economic factors and their interrelation with biophysical factors, of a potential agricultural system have to be understood, in order to develop concrete system-adjusted biochar systems, which enhance the probability to maximize the potential benefits and diminish the negative effects and revealing potential trade-offs (Jeffery et al. 2013: 2; Leach 2010: 4).

3. Theoretical framework

3.1. Vulnerability

The concept of vulnerability is the starting point of the construction of the theoretical framework that guides the methodology and the analysis of this research work. The term vulnerability with respect to environmental or social risk to humanity is used in scientific as well as in political contexts (Bohle 2007: 20; Schütte 2004: 4). However, the usage of vulnerability is varying, apparently based on the same definitions, approaches and applications illustrate that the concept of vulnerability is not always understood the same way (Birkmann and Wisner 2006: 10; Brooks 2003: 2ff; Downing and Patwardhan 2004: 71; Gallopìn 2006: 294; Hinkel 2011: 198; Schütte 2004: 4).

Figure 2 visualizes an extract of the development paths of the concept of vulnerability in environmental and social science and illustrates that definitions are often referred and interlinked across these two research branches. Theoretical and practical research based on the concept of vulnerability is various. The illustration hence does not claim to depict this development in detail, but should serve as an orientation within the broad outgrowth of research inspired by vulnerability.

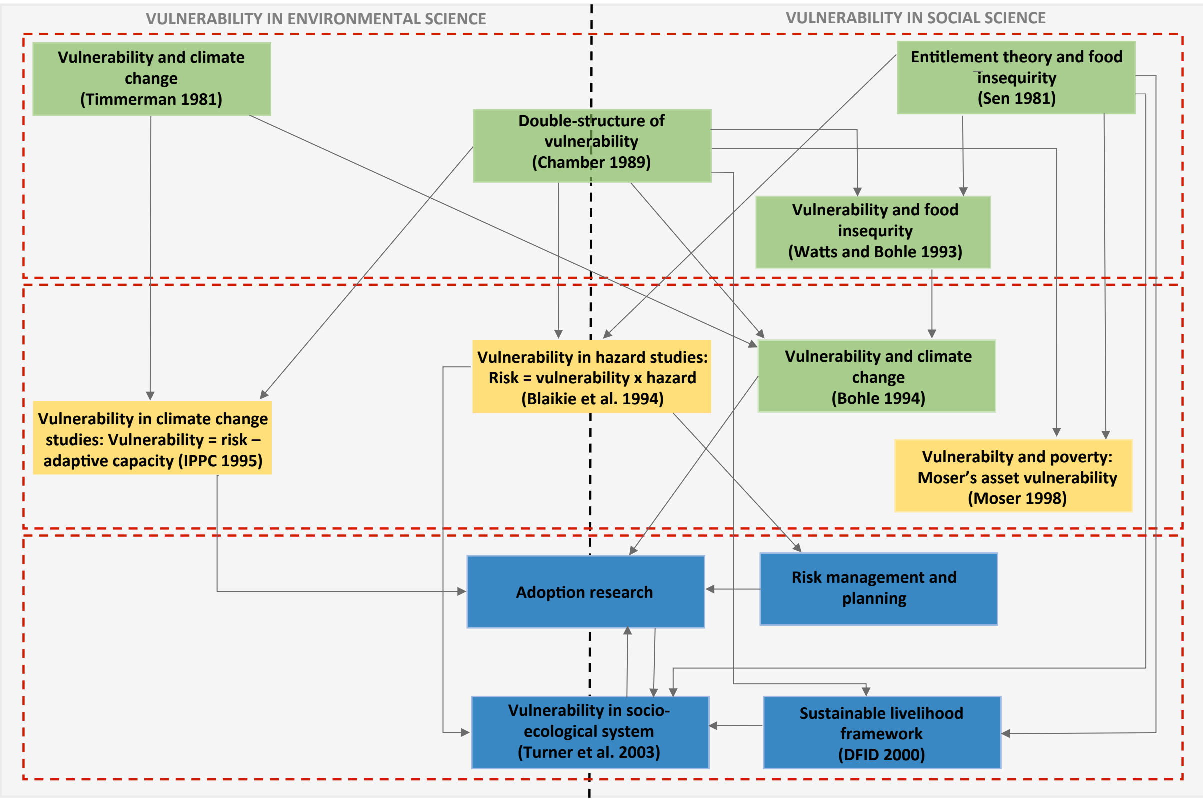

Figure 2: Development of the concept of vulnerability in environmental and social science. Green coloured boxes are crucial theoretical assumption of the constitution of vulnerability regarding environmental and social risks. Based on these theories the concept of vulnerability was applied in order to assess vulnerability to define suitable adaption and mitigation strategies regarding environmental and social threats. Whereas in the beginning the focus has been on the capture of current or static vulnerabilities of different people, environments or places (yellow boxes), vulnerability as dynamic concept that changes continuously is determining current research of vulnerability (blue boxes)) (own representation).

Common within approaches between and within social and environmental science is an understanding of vulnerability as a construction that is characterized by its bi-directionality (Birkmann and Wisner 2006: 10). Chambers (1989) explicitly formulated this relationship in 1989 (cf. Watts and Bohle 1993; Kasperson et al. 2005). Vulnerability accordingly has two sides: an external side that is referred to “risks, shocks and stresses” and an internal side that is referred to the capacity of the system, household or individual “to cope without damaging loss” (Chambers 2006: 33). Vulnerability hence is determined by the interplay of its external and internal side. An enhancement of the internal side, respectively the development of normative actions to improvement of mitigation or adaption strategies to better cope with external risks, shocks and stresses, accordingly is the main driver of vulnerability assessments (Adger 2006: 269).

Initially based on the same ontological understandings of vulnerability and the same motivations to conduct vulnerability assessments, there are fundamental differences between and within the different vulnerability assessments. These differences are caused due to different epistemological approaches (Brooks 2003: 2; Adger 2006: 279). Either it is understood as an end-point of analysis, thus an outcome of future environmental or social changes or it is understood as a starting-point of analysis, thus an internal property of an individual or system that alters regarding future environmental or social changes. To assess vulnerability either end-point or starting point-oriented, two approaches were distinguished: a rather static approach, that focuses on a determination of a snapshot of vulnerability, or a process-oriented approach, that seeks to optimize the implementation process of mitigation or adaption strategies regarding environmental and social changes.

In the following sections include i) an overview about first attempts to grasp vulnerability, ii) examples of snapshot vulnerability assessments in both social and environmental science and iii) an overview about process-oriented assessments and iv) the concept of the socio-ecological system as an analytical unit to grasp individual or system-specific vulnerability in order to identify relevant factors, that determine the process of mitigation or adaption strategies regarding environmental and social changes. The chapter concludes with a synthesis where the theoretical conceptual framework of this study is illustrated.

3.2. First analytical attempts to grasp the causes of social vulnerability

The concept within environmental and social studies emerged in the early eighties of the 20th century (Bohle 2007: 20; Schütte 2004: 4). In 1981 Timmerman (1981) and Sen (1981) published first attempts of a theoretical approach to grasp vulnerability. Within the environmental research branch Timmerman (1981: 1) draws on previous debates of the climate change society on the consequences of climate change on society and concludes with advising to particularly focus on strategies “being used by various societies to protect themselves from uncertainties” in order to reduce vulnerability caused by climate change and enhance “reliabilities or resiliencies” (Timmerman 1981: 38). At the same time Sen (1981) published his work on entitlement theory, which is rooted in socio-economic science (O’Brien et al. 2004 [a]: 3). Entitlement theory explains the occurrence of poverty and the often related famine not as being primarily caused by a “significant decline in total food availability” (Dréze and Sen 1989: as cited in Watts and Bohle 1993: 118) due to “shortfalls in food production through drought, flood, or pest”, but as a result of a lack of access to a “set of linked economic and institutional” resources (Adger 2006: 270; O’Brien et al. 2004 [a]: 3; Sen 1990: as cited in Bohle et al. 1994: 40).

In 1993 Watts and Bohle (1993: 117) extended the entitlement theory in order to construct a space of social vulnerability regarding food security. Vulnerability in their understanding is “a multi-layered and multi-dimensional social space defined by the political, economic and institutional capabilities of people in specific places at specific times” (Watts and Bohle 1993: 118). To grasp the space of vulnerability in food security they combined entitlement theory with political economy and empowerment theory in order to define three factors that are defining the space of vulnerability, which were: i) distribution of entitlements and how they are reproduced in specific circumstances, ii) rights by which entitlements are defined, iii) structural properties of political economy (ibid. 1993: 117).

Within this space three basic coordinates are defining the localisation of vulnerability. The definitions of these coordinates are based on Chamber's (1989: Watts and Bohle 1993) construction of vulnerability. Vulnerability accordingly is determined by the interplay of its external and internal side. The external side hereby is referred to "risks, shocks and stresses to which an individual and household is subject" and the internal side is referred to the capacity "to cope without damaging loss" (Chambers 2006: 33). According to Watts and Bohle (1993) the outcome of this interplay determines the basic coordinates of vulnerability: i) risk of exposure to crises, stress and shocks, ii) risk of inadequate capacities to cope with stress, crisis and shocks, iii) the risk of severe consequences of, and the attendant risks of slow or limited recovery […] from crises, risk and shocks (Watts and Bohle 1993: 118).

Based on the illustration about vulnerability to poverty and famine (Watts and Bohle 1993), Bohle et al. (1994) applied the construction of a social space of vulnerability, to vulnerability to climate change. The space where vulnerability regarding climate change is located is thereby defined by human ecology, expanded entitlements and political economy (Bohle et al. 1994: 37). Human ecology "refers to the relations between nature and society", how society has "direct implications for sustainability" and how the environment "is experienced in terms of risks and threats" (ibid. 1994: 40). Expanded entitlement in this context includes "not only ownership […] [of physical and human resources (Swift 1989: as cited in Bohle et al. 1994)], but wider social entitlements and the necessary empowerment […] by which entitlements are secured, fought over and contested" (ibid. 1994: 40). Political economy in this sense represents the wider economic-political structure where especially "class processes" define the outcome of "risks and threats experienced by vulnerable groups" (ibid. 1994: 40).

These illustrated theoretical outlines were first attempts to grasp the nature of vulnerability. Practical oriented research, with the intention to determine suitable adaption and mitigation strategies in order to reduce vulnerability, needed to operationalize the theoretical concept of vulnerability. In environmental and social science there are different ways of making the theoretical concept of vulnerability operational. Within the next sections a static and a process-oriented assessment of vulnerability is differentiated. In social and environmental studies, both assessments are represented. The results however depend on the epistemological understanding of vulnerability. Either vulnerability is understood as an outcome of future environmental or social changes or vulnerability is understood as an inherent property that alters regarding environmental or social changes.

3.3. Snapshot-vulnerability

Snapshot assessments of vulnerability are static in their nature (Leichenko and O'Brien 2002: 3). Static approaches attempt to determine vulnerability of specific people or places in order to define the level of vulnerability or risk regarding an external impact to define suitable policy or technological measures to reduce vulnerability (O'Brien et al. 2004[a]: 5).

3.3.1. Assessment of snapshot-vulnerability in environmental science

Generally snapshot-vulnerability assessments in environmental science are end-point or outcome-oriented. However O'Brien et al. (2004[a]: 4) differentiate between two generations of vulnerability assessment in environmental science: a starting-point and an end-point approach. The first generation of vulnerability assessment is an end-point approach, thus vulnerability is understood as an inevitable outcome of climate change. Methods to assess vulnerability are basically scenario-based. The second generation is a starting-point approach, where vulnerability is understood as a context-specific outcome of climate or social change scenarios. Vulnerability is understood a function of multiple future climate and social exposures, place-specific sensitivity and adaptive capacities.

3.3.1.1. Vulnerability-scenarios

The use of scenarios to assess future vulnerability is dominantly used within analysis of vulnerability documented in the traditional IPPC report. The approach of vulnerability of the first generation of climate change studies is outcome orientated (Downing and Pathwardhan 2004: 71; Handmer et al. 1999: 267). This gets evident by taking a closer view on how vulnerability is defined within the traditional IPPC report (Brooks 2003: 4; Downing and Patwardhan 2004: 71):

Vulnerability = risk - adaptive capacity

Vulnerability within the outcome approach assumes, that climate change is the main problem that causes vulnerability (O'Brien et al. 2004[a]: 5). Accordingly the aim of research is a determination of future vulnerability caused by changing climatic conditions (Brooks 2003: as cited in O'Brien et al. 2004[a]: 3). This future vulnerability, as defined in the equation above, is the residual of impacts of climate change determined by the *adaptive capacity* of a system (O'Brien et al. 2004[a]: 3). A high adaptive capacity regarding external risk or climate change, results in low vulnerability and vice versa. Adaptive capacity is either hypothetical estimated or based on different mitigation strategies, such as implementations of supportive technologies (Smit and Wandel 2006: 284). The outcome vulnerability thus "summarizes the net impact of the climate problem, and can be represented […] as a monetary cost, or […] as a description of relative or comparative change [change of yield or flow, human mortality, ecosystem damage]" (O'Brien et al. 2004[a]: 2). Based on the outcomes a definition of adaptive capacity enhancement strategies might be possible.

3.3.1.2. Vulnerability maps

Different than within the first generation of climate change research, vulnerability assessment within the second generation is contextual-oriented. Vulnerability is understood as a function of multiple exposures and place-specific sensitivity and adaption capacity (Adger 2006: 274; Locatelli et al. 2008: 6). Exposure is understood as "the nature and degree to which a system is exposed to significant climatic [and/ or social variations]" (IPPC 2001: as cited in Brooks 2003: 5). Sensitivity is "the degree to which a system [is modified] or affected", and adaptive capacity is "the ability of a system to adjust to climate and [and/ or social change] […][in order] to cope with the consequences" (ibid. 2003: 5).

O' Brien et al. (2004[b]) implemented this approach and developed an indicator-based vulnerability map, which locates the contextual and thus relative and space-specific vulnerability of the Indian agriculture sector regarding multiple exposures. To gather vulnerability in its context, they developed indicators, which express space-specific adaptive capacity and sensitivity (O'Brien et al. 2004[b]: 305). For adaptive capacity they identified bio-physical, socioeconomic and technological factors, which influence agricultural production. For sensitivity they used a climate sensitivity index, consisting of measurements of "dryness and monsoon dependence based on a gridded data set" (O'Brien et al. 2004[b]: 307). To simulate multiple exposures, they used data based on climate change scenarios and data of the liberalization change of agricultural trade (O'Brien et al. 2004[b]: 207f).

Based on these outcomes they conducted case studies within regions that were detected to be highly vulnerable, in order to identify "state and local-level institutions and policies that influence [place-specific] coping and adaption strategies" (O'Brien et al. 2004 [a]: 309). These insights in turn, were intended to provide a basis for the development of suitable policies options and measures in order to improve the vulnerability-context and "build local capacity" "to set the context for future adaptions" (O'Brien et al. 2004[a]: 4f; O'Brien et al. 2004: as cited in Naess et al. 2006: 222).

3.3.2. Assessment of snapshot vulnerability in social science

In social science, vulnerability is basically understood as an internal property of the system, thus assessments are start-point oriented (Adger 1999: 249). Two approaches of assessing start-point vulnerability in social science are natural hazard and livelihood studies.

3.3.2.1. Natural hazard and risk maps

Similarly than traditional climate change assessments of vulnerability, natural hazard research is impact-driven. But vulnerability in natural hazard studies is not seen as a consequence of the impact itself, vulnerability is rather understood as "systemic and a consequence of the state of development" (Downing and Patwardhan 2004: 71). Accordingly vulnerability is defined as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard" (Blaikie et al. 1994: 9). In other words the extent or the consequences of a hazard on the affected society is determined by the inherent vulnerability of the system (Birkmann 2007: 21; Brooks 2003: 6; Clark et al. 1998: 59).

In natural hazard theory a distinction is made between the occurrence and the impact of a specific hazard on the society (Brooks 2003: 6). Hazard on the one side is defined as "a natural or manmade phenomenon that may cause physical damage, economic loss and threaten human life and wellbeing" (Chiwaka and Yates 2005: 6). The impact on the society on the other side is equated with risk and is defined as "the expected damage or loss due to the combination of vulnerability and hazards" (ibid. 2005: 6). The interrelation between hazard, vulnerability and risk in natural hazard theory are summarized in the following equation (Blaikie et al. 1994: 23; Brooks 2003: 4; Downing and Patwardhan 2004: 71):

Risk = Vulnerability x hazard

This view on vulnerability is related to the "pressure and release model" (Blaikie et al. 1994: 21). The "pressure and release model" is based on the understanding, that a disaster is the result of the "intersection of two opposing forces": Vulnerability on the one side and physical exposure on the other side (ibid. 1994: 22; Clark et al. 1998: 59). This understanding directs to two cruciate assumptions: and i) vulnerability is hazard-specific (Birkmann 2007: 21; Brooks 2003: 4); and ii) as the physical exposure in most cases is not evitable, as a consequence to release pressure, hazard-specific vulnerability has to be reduced (Blaikie et al. 1994: 22).

Vulnerability assessment in traditional natural hazard studies accordingly focuses on the identification of how the inherent vulnerability of a system, household or individual might specifically alter due to the occurrence of hazards and how this hazard-specific vulnerability might best be reduced (Cutter et al. 2000: 713). A widespread application of hazard research theory based assessments is risk mapping. To map risk first the spatial dimensions of hazard were identified. This identification is based on biophysical indicators (ibid. 2000: 713). To identify the inherent vulnerability accordingly to a specific hazard, social indicators are applied (ibid. 2000: 713). This determination of social indicators is based on entitlement theory and thus on the assumption, that "fundamental causes of human vulnerability include a lack of access to resources, information, and knowledge, and limited access to political power and representation" (Blaikie et al. 1994: as cited in Cutter et al. 2000: 717). In most cases socio-environment census data were utilized as indicators (Clark et al. 1998: 67). As a result a risk map represents a localisation of where people especially "are at risk due to a potentially catastrophic event" (Birkmann 2007: 20; Edwards et al. 2007: 4). On the basis of this map, similar than in climate change studies of environmental science, suitable risk management strategies might be established, in order to reduce hazard-specific vulnerability.

3.3.2.2. Asset-vulnerability

Moser (1998) developed an asset vulnerability framework, based on the poverty reduction debates of the nineties. Contrary to neo-liberal poverty reduction strategies of the World Bank, where generalized strategies were implemented, such as: i) economic growth by "using the poor's labor", ii) investments in basic health and education and iii) provision of social safety nets to protect vulnerable groups and the very poor - Moser (1998) emphasized a participatory approach "to strengthen people's own inventive solutions" (Geiser et al. 2011: 258; Moser 1998: 2). The focus hereby is on the micro-scale - on the identification of "what the poor have rather than what they do not have" (Moser 1998: 2). This includes an identification of their tangible and intangible assets, such as human, financial, social, physical and natural assets[1] and as well of their "positive and negative potential coping strategies and outcomes" (Moser 1998: 5; Schütte 2004: 1).

This understanding of poverty implies a distinctive view on poverty, which is often associated with a high vulnerability level. Moser (1998: 3) states: "Although poor people are usually among the most vulnerable, not all vulnerable people are poor." Moser (1998) refers hereby to Chambers (1998: as cited in Schütte 2004: 40) definition of a two-dimensional vulnerability, where an analysis of vulnerability has to involve "not only threat but also […] responsiveness in exploiting opportunities" (Moser 1998: 3; Schütte 2004: 4). Individuals, households or communities in this sense are more vulnerable in facing risks, if their ability to cope and recover from crisis is limited (Schütte 2004: 41). The ability to cope herby is strongly tied to the composition of assets that the poor own and what their "possessions enable them to do" (Moser 1998: 5; Sen 1981: as cited in Schütte 2004: 40). Accordingly vulnerability is linked to asset ownership: "The more assets people have the less vulnerable they are and […] the greater their insecurity." (Philip and Rayhan 2004: 5). An assessment of the assets, that the poor own and hence a classification of "the capabilities of poor populations", helps to identify suitable poverty reduction strategies (Moser 1998: 14).

[1] *Human assets* refer to knowledge, skills, formal education and good health. *Social assets* refer to the capability of individuals to secure resources such as time, information, money and membership in social networks. *Financial assets* refer to the economic resource base in general, e. g., to access to income opportunities, to stocks that are at the household's disposal and to regular inflows of money. *Physical assets* refer to both productive assets and household assets. Productive assets include basic infrastructure such as shelter, water supply, sanitation, waste disposal, energy supply, and transport, but also tools and production equipment required for income-generating activities or enhancement of labour productivity. *Natural assets* refer to endowments with natural resources and institutional arrangements controlling access to common property resources. (cf. Schütte 2004: 41)

3.4. Process-oriented assessments

A process-oriented assessment focuses "on the implementation processes for adaption" (Locatelli et al. 2008; Smit and Wandel 2006: 285). This differs to a static approach, where decisions about suitable adaption and mitigation capacity enhancements were developed, founded on a scenario-, indicator- or asset-based determination of vulnerability. Central within a process-oriented approach is moreover the identification of causes of social differences in adaption processes. This includes a local-, or participatory-based starting-point assessment of vulnerability, in order to determine the causes of social differences within an adaption process (Locatelli et al. 2008: 5).

3.4.1. Rethinking in vulnerability assessment approaches

In climate change studies the growing awareness of the disability of "snapshot" vulnerability assessments to identify adaption barriers, led to a rethinking of how the suitability of adaption capacity enhancements towards climate change might be best assessed (Leichenko and O'Brien 2002: 3; Smit and Wandel 206: 285). Traditional top-down approaches using scenarios or indicators to determine vulnerability, where complemented or exchanged by practical bottom-up vulnerability assessments, which are intended to "facilitate adaptions" by the identification of suitable adaption strategies originated by local stakeholders (Füssel and Klein 2006: as cited in Naess 2006: 221). This approach modifies the classical way of science of generating knowledge to a practical-oriented, applied science that emphasises a policy-relevance (Kasperson 2011: 3).

There are two ways, which were identified within climate change literature, to apply this new thinking in vulnerability or adaption assessments. A rather "soft" way, which aims to understand decision-making difficulties with local stakeholders that occur during the evolution processes of suitable policies and measures for an enhancement of adaption capacities based on previous determined spatial vulnerability assessments (cf. chapter 4.3.1.2.; e. g. Ernst and Riemsdijk 2013); and a rather strict way, which "tends not to presume the specific variables that represent […] [vulnerability] but seeks to identify these empirically from the community" (Smit and Wandel 2006: 285). Vulnerability assessment accordingly and specifically adaption capacity enhancement actions by applying such an approach are then both grounded on local knowledge.

The "soft" way analyses the use of climate change vulnerability assessments for concrete local decision-making contexts (Naess et al. 2006: 221). The focus hereby lies specifically on the usefulness of information, a vulnerability assessment can provide, and the ability to make use of it, within a specific, local context (ibid. 2006: 221). Crucial for the usefulness thus, is the institutional context, as illustrated by Naess et al. (2006). Accordingly, especially "established sectorial structures, policies and interests are potential barriers for a comprehensive integration of adaption perspectives in local policies" (Handmer et al. 1999: 297; Naess et al. 2006: 227). Another factor is the information transfer. As Naess et al. (2006: 225) experienced, local stakeholders as such, confirm generally "scepticism to the local usefulness of uniform vulnerability indicators", such as utilised for vulnerability maps or scenarios. Assessments based on such uniform indicators, thus have to involve likewise local contexts, in order to better grasp local reality (All and Norland 2004: as cited in Naess et al. 2006: 225). On the other hand, as Naess et al. (2006) conclude, that "locally anchored assessments […] [might] result in misleading conclusions by overlooking the implication of regional or national-space patterns and processes" (Wilbanks and Kates 1999: as cited in Naess 2006: 225). A local-oriented vulnerability assessment thus includes both a macro-, or meso-scale spatial assessment of vulnerability and a micro-scale assessment with a constant dialogue with local stakeholders.

In the “strict” way, as illustrated by Smit and Wandel (2006: 281), vulnerability and thus adaptive capacity are understood as strongly place-, system- and context-specific. A vulnerability assessment accordingly starts within a specific community at a specific place and context. The researcher hereby “does not presume to know the exposure, sensitivities […] or adaptive capacities in the community”; the characteristics of vulnerability are contrary determined by the stakeholders themselves (ibid. 2006: 288). Such “participatory vulnerability assessments” are not intended to determine vulnerability regarding a specific stimulus, they rather “allow for a recognition of multiple stimuli beyond those related to climate, to include political, cultural, economic, institutional and technological forces” (ibid. 2006: 188). The aim of research is thus to “attain information on the nature of vulnerability” based on local knowledge, in order to identify place-, system-, and context-based adaption actions to reduce vulnerability (ibid. 2006: 289).

These approaches are strongly in line with social science understandings of vulnerability and adaption. Thus vulnerability and adaption in social science are understood as internal and place-, respective strongly context-specific characteristic of an individual or a system. In natural hazard research the application of uniform, discrete indicators to determine spatial vulnerability or risk, therefore was criticised (Bankoff et al. 2004: 2; Birkmann 2007: 21; Mueller and Dooling 2011: 202; Stephen and Downing 2001: 114). Homogenous indicators thus contradict to the initial assumption of a place-, or context-specific vulnerability. Stephen and Downings (2001: 115) question the validity of interpretations “from one scale to another”, because “processes appearing homogenous at an aggregated scale may be heterogeneous at finer scales”. To enhance results based on indicator-based risk maps, either additional qualitative data should be integrated in order, “to achieve a more comprehensive picture about risk and vulnerability” (Birkmann 2007: 114; Stephen and Downing 2001: 118) or risk maps should be developed directly based on local knowledge (Tran et al. 2008).

A realisation of the former approach was made by Hernández-Guerro et al. (2012). In their study a “flood-model” and a “precarious-housing model” of Morelia, México, were applied to determine “risk-prone areas” (ibid. 2012: 71). Based on these results two qualitative case studies within these “risk-prone areas” were conducted, in order to “gather and compare the adaptive strategies” of the people living in these areas (ibid. 2012: 71). The latter approach is realised in particular participatory risk management research (e. g. Chiwaka and Yates 2005; Mueller and Dooling 2011; Tran et al. 2008). Particular participatory risk management focuses on natural hazard “perceptions, adjustments and management” of local stakeholders (Smit and Wandel 2006: 284), not only to identify strategies “implemented by people living under precarious conditions” (Hernández-Guerro et al. 2012: 669), but as well to identify hazards or “risk-prone areas” specifically based on local knowledge. As Tran et al. (2008: 2) mentioned, traditional “disaster risk programmes […] failed to induce people to participate”, because they “have lacked both the will and the instruments to allow people to use their own knowledge”. Tran et al. (2008: 8) accordingly used qualitative methods, such as focus groups to identify local knowledge based factors “that contribute to […] [hazard] vulnerability” and quantitative methods, such as a geographic positioning system to locate hazard-specific vulnerable places, based on the previous identified local knowledge based factors.

Likewise within the entitlement theory, respective in livelihood approach the asset-based determination of vulnerability was questioned and incorporated within a wider sustainability context. Equally to traditional livelihood approaches (cf. chapter 4.3.1.2.), the sustainable livelihood approach focuses on people and how these "people trying to make a living" (Carney 2003: 9; Murungwendi et al. 2011: 1). In 2000 a sustainable livelihood framework was developed, which intends to function as a tool to grasp the multi-dimensionality of a sustainable livelihood. The sustainable livelihood framework consists of five sections: i) a vulnerability context, ii) livelihood assets, iii) transforming structures and processes, which are referred to institutions and organisations iv) livelihood strategies, and v) livelihood outcomes (DFID 2000: as cited in Tang et al. 2013: 17). An application of this framework, provides the basis to understand the "outcome of relations based on the interaction between different […] assets, [strategies and activities], […] "mediated [and constraint] through transforming structures and processes", and embedded within a vulnerability context (Baumann 2000: 5; Chen et al. 2013: 908; Geiser et al. 2011: 259; Murungwendi 2011:1; Reed et al. 2013: 67; Tang et al. 2013: 17).

Vulnerability in this sense is understood as an expression of the accessibility to assets, which is framed and constraint by institutional factors. By adding the concept of sustainability into the approach, the rather static representation of livelihood conditions of the poor (cf. chapter 4.3.1.2.) is expanded by adding a hypothetical time dimension: a sustainable development process "should meet the needs of the present generation without compromising the options of future generations" (Morse et al. 2009: 6). Livelihoods accordingly are sustainable, when they "can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resources base […] and provide sustainable livelihood opportunities for the next generation" (Chambers and Conway 1992: as cited in Morse et al. 2009: 4; Cramb et al. 2003: 258; Murungwendi et al. 2011: 1). Or in other words, a sustainable livelihood is resilient, thus it owns a capacity to recover, so that it is able to provide the same "sustainable livelihood opportunities for the next generation" (Obrist et al. 2011: 278; Van der Leeuw 2001: as cited in Gallopìn 2006: 295)

Reed et al. (2013: 68) mention reasons how the sustainable livelihood framework can help to understand the causes of vulnerability of individuals or households. The framework provides a tool to identify why certain individuals or households are more "sensitive or exposed to their ability to cope with" perturbations, stresses or hazards and "how livelihood strategies can build adaptive capacity to enable people to better cope with change, and diversify their activities to increase resilience for unforeseen future change" (Reed et al. 2013: 67). Likewise while taking the formal and informal institutions context into the picture, it recognises "that it is often access to […] assets that is most limiting livelihoods", hence accessibility to assets is strongly tied to institutions "that constrain and shape social behaviour" (Reed et al. 2013: 68).

However an application of the sustainable livelihood framework to identify local-, and context-specific causes of vulnerability has certain weaknesses. Applying a sustainable livelihood framework might help to illuminate internal dynamics and coherence of livelihood assets, strategies and activities embedded within a vulnerability and an institutional context, but it does not capture the internal dynamics within the assets themselves (Reed et al. 2013: 68). It rather emphasis the variations of [access to] stocks of assets […] than the variations of flow of services that those assets provide (ibid. 2013: 86). Regarding climate or social change, the flow of these assets might change over time, "without necessarily altering overall stocks" of assets (Adger 2006: 272; Reed et al. 2013: 68). Likewise it provides an understanding of the "operational, technical and legislative factors that influence livelihood at the local level", but it does not include the wider exogenous context, which, particularly within a globalised world, as well influences the local context (Baumann 2000: 6).

3.4.2. Analytical attempts to grasp dynamical vulnerability

The new understanding in social and environmental science of vulnerability as being dynamic (De Chazal et al. 2008; Smit and Wandel 2006), led to an application of socio-ecological system as an analytical unit to understand and assess the dynamics of vulnerability.

The application of the concept of a socio-ecological system as an analysis unit to analyse and assess vulnerability brings environmental and social science together (Adger 2006: 269). However results of an analysis are different, because they likewise depend on previous defined epistemological assumptions. The epistemological differences are caused, as previously described, on the understanding of whether vulnerability is understood as an outcome of impacts or if vulnerability is understood as an inherent property of the system, which is altered by the impacts. If vulnerability is understood as an outcome of impacts, vulnerability thus is an "attribute of the relationship between the system and the [exposure caused by the impacts]" and not of the system itself (Gallopìn 2006: 297). This understanding of vulnerability is particularly assumed in environmental science, such as within the second generation of climate change research (cf. chapter 4.3.2.1). Otherwise vulnerability is understood as an inherent property of the system, how it is particularly assumed in social science (Smit and Wandel 2006). Exposure in such an understanding is excluded of the system-specific vulnerability. Regarding an inexperienced exposure, the system-specific vulnerability might alter. The inexperienced exposure thus becomes a "relational property" of the vulnerability, but not per se a property of the vulnerability itself (Gallopìn 2006: 297).

Gallopìn (2006) illustrates the mechanisms and processes of an alteration of the system-specific vulnerability regarding an inexperienced exposure. He understands the system-specific vulnerability as well as an internal property of the system and differentiates between a constantly occurring exogenous and endogenous disturbances and perturbations that define the system-specific vulnerability, and inexperienced exposures, such as future environmental and social changes. In cases of inexperienced exposures the vulnerability of the system alters dependent on the capacity of response and the sensitivity of the system regarding these specific exposures (ibid. 2006: 295). The capacity of response is understood as being dependent on the resilience and the adaption capacity of the system (ibid. 2006: 301). The resilience is representing the function of the system. The adaptive capacity is the systems ability to adapt to specific exposures. Sensitivity is "the degree to which a system is modified or affected by a transformation", thus is an expression of "whether a system is sensitive to a given factor or not" (ibid. 2006: 295; cf. figure 3).

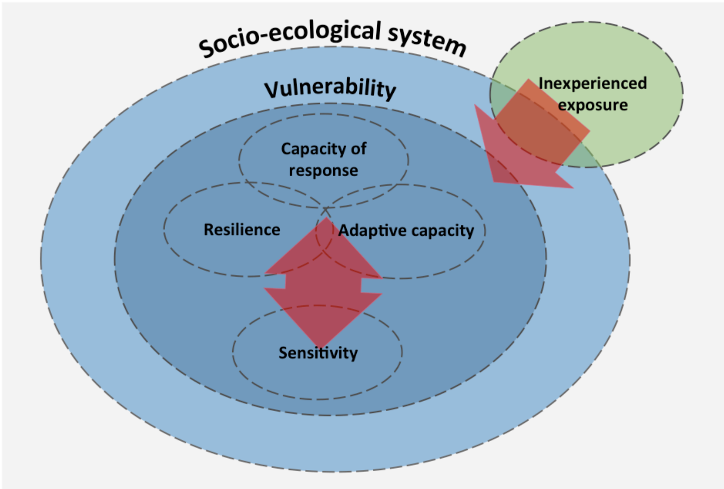

Figure 3: Alteration of vulnerability within a socio-ecological system (References: Gallopìn 2006**)** (own representation).

The application of the concept of a socio-ecological system in social science to assess and analyse vulnerability emerged by combining the insights of the entitlement theory, respectively sustainable livelihood approach and the natural hazard research. While natural hazard research moreover focused on the conceptualisation of the linkages and influences between and within socio-economic and biophysical systems and potential alterations of these systems and their outcomes in terms of risks, the sustainable livelihood approach "succeeded in highlighting social differentiation in cause and outcome of vulnerability" (Adger 2006: 271). Vulnerability accordingly, based on the insights of natural hazard research, is a result of the dynamics between and within the socio-economic and biophysical subsystems. With respect to the insights sustainable livelihood approach, this vulnerability however is not homogenous distributed, caused by the differences of accessibility of individuals, groups or communities to livelihood assets, strategies and actions (Adger 2006: 268; Schröter et al. 2005: 575).

Individuals, groups or communities thus are acting and reacting based on their accessibility to assets within a socio-ecological system that is constantly confronted with disturbances or perturbations, caused by the dynamics between and within the socio-economic and biophysical subsystems. As a consequence the system is building a system-specific function and structure. The structure is on the one side based on the "set of entitlements" or assets that are available within the system and on the other side, as not every individual, group or community is having access to the entire set of entitlements; on the cumulative different reactive strategies or actions of the individuals, groups and communities that are facing disturbances and perturbations (Adger 1999: 252). In this sense it is the social differentiated adaptive capacities or cumulated individual vulnerabilities that are constructing and preserving the structure of the system (Cannon et al. 2003: 6; Van der Leeuw 2001: as cited in Gallopin 2006: 295). The function is a result of the systems resilience or "capacity to recover" (Adger 2000: 349; Van der Leeuw: as cited in Gallopìn 2006: 295). A system would stop functioning, if it would not be resilient (Young et al. 2006: 306). Sources of resilience can likewise be found within the sets of entitlements or assets, strategies or actions of the individuals, groups or communities (Kasperson and Dow 2005: 148). However within a system that is functioning and in this sense is resilient, its individuals, groups or communities are not consequently invulnerable.

On the other hand an alteration of the resilience, thus the function of the system, caused by an inexperienced exposure, affects the level of vulnerabilities of individuals, groups or communities, dependent on their adaption capacity, or accessibility to assets. Simultaneously an alteration of the individual vulnerabilities, caused by modifications of the accessibility to assets, might change the structure of the socio-ecological system and thus the function of the system.

3.5. Synthesis

Regarding a hypothetical implementation of a biochar system into a socio-ecological system, the alteration of the system's vulnerability is not directly observable. Thus it is not observable how sensitive a socio-ecological system reacts due to an implementation of a biochar system. Indirectly it is possible to assume the potential alteration of vulnerability by determining the system-specific capacity of response regarding an implementation of a biochar system. As illustrated in the previous chapter, capacity of response is the systems ability to respond to specific exposures, in this sense to a biochar system, and is an outcome of both, the resilience and the adaptive capacity of the system. Dependent on the condition and alteration of the system-specific resilience and adaptive capacity, adaption barriers regarding a sustainable implementation of a biochar system might be identifiable (cf. figure 4).

To assess the internal resilience of the social-ecological system all possible assets, strategies and actions regarding exogenous and endogenous disturbances and perturbations and how they are framed and constrained within an institutional frame, have to be identified and set into relation. The result provides a mirror of the function of the system or how it is capable to recover. To grasp the adaptive capacity, the access to these different assets, strategies and activities have to be examined, because not every individual has equal access to this system-specific set of assets, strategies and activities. In this sense, all the different levels of individual vulnerabilities have to be examined.

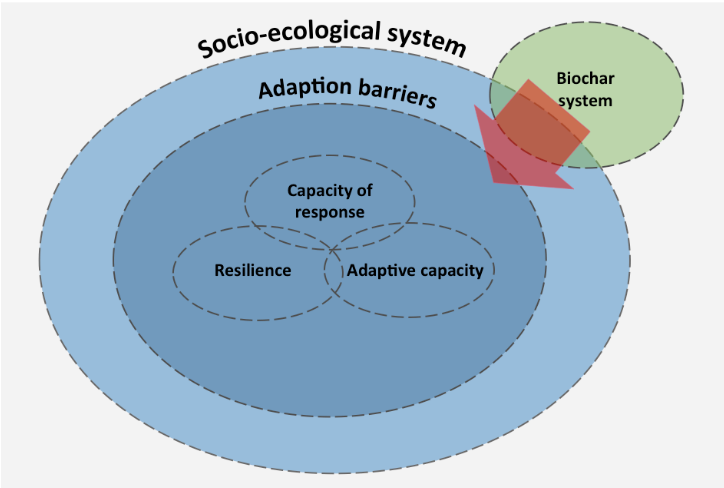

Figure 4: Conceptual framework to assess adaption barriers regarding a sustainable implementation of a biochar system (own representation).

An implementation of a biochar system alters the resilience of the system, and hence indirectly alters the social differentiated or individual vulnerabilities, because it alters the function and thus the structure of the system. Likewise an alteration of the social differentiated or individual vulnerability alters the structure of the system and therefore the function of the system. An implementation of a biochar system in this sense always represents a trade-off between "building resilience" and "reducing vulnerability" (Adger 2009: 342).

4. Research area

The selection of a suitable research area was guided by two main distinction criteria, which are (i) annual precipitation and (ii) agricultural production. These two distinction criteria were chosen in order to make conclusions if the suitability of an implementation of a biochar system is dependent on specific climate and/ or agricultural productions. For these reasons one research area had to be located in a dry and the other in a wet region. Likewise, within the regions either paddy or sugarcane production was chosen as dominant agricultural production.

Based on the agro-climatic zones of Karnataka that are dividing the federal state into ten zones according to their physiography, soils, bio-climate and length of growing period (Shiva Prasad et al. 1998: 5), and previous expert interviews with local soil scientists, Mandya district and Udupi district were selected. Mandya district is located within the Southern dry zone where climate is generally hot and dry. Udupi district is located within the Coastal zone where climate is generally humid and hot (Shiva Prasad et al. 1998: 6f). Figure 1 illustrates the geographic location of the two mentioned districts.

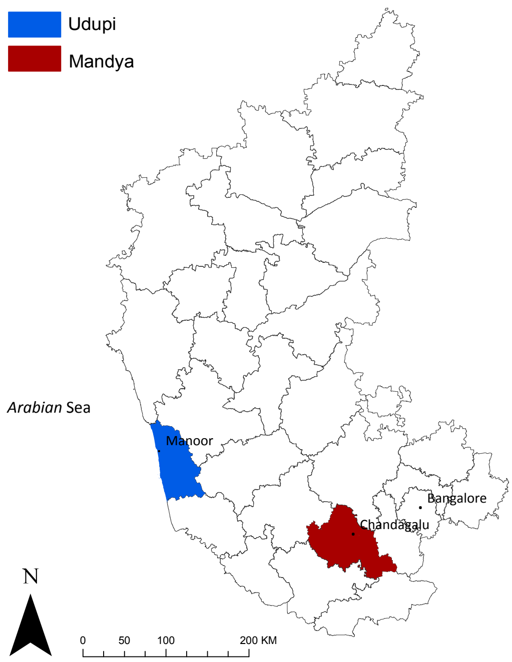

Figure 5: Geographic location of Manoor within the district of Udupi and Chandagalu, which is located within Mandya (GIS-Data: Agricultural University of Bangalore) (own representation).

Within the chosen regions two villages were selected by using five pre-defined criteria, in order to enable a subsequent comparison between the two chosen villages.

- Easy access
- Relative small number of inhabitants
- Variation of high and low quality soil
- Use/ non-use of ash
- Use/ non-use of biogas

The specific villages that were concerned, were chosen based on informal information of agriculture extension workers, local students and members of local Panchayats. This approach was used, because no official data was recorded or easily available (Sing & Chopra 2007: 133). For Mandya co-supervisor Dr. N. B. Prakash provided contacts to the local VC farm, which is a college of agriculture. The first day of arriving, expert interviews with two soil scientists of the institution were conducted, whereby a local village assistant was provided to make first contacts with local farmers. The village assistant proposed seven villages within the closer area that would fulfil the pre-defined criteria. For further information about the mentioned villages, the topic of research was presented to local students of the VC farm, in order to complement the profiles about the different villages. Additionally a professor of the local students and his assistant provided access to local cadastral maps and contacts to responsible persons of the Panchayats of the mentioned seven villages. Hence the relevant Panchayats were visited and Panchayat members provided the necessary numbers. Accordingly to these information, the village Chandagalu was selected (cf. figure 5).

In Udupi a contact to an extension worker of the local agricultural department, was provided by co-supervisor Dr. N. B. Prakash. On the date of the first visit a farmer's assembly called Krishi Mela took place in Udupi. By visiting the Krishi Mela a first meeting with the local extension worker was possible. The local extension worker proposed the village Manoor with respect to the provided criteria. Farmers of the mentioned village that were attending the Krishi Mela as well, could directly provide more information and as a result the village Manoor was selected as second case study (cf. figure 5).

4.1. Chandagalu

Chandagalu is located in the district of Mandya (12°31'22" N, 76°54'24" E) within the South Deccan Plateau region. The South Deccan Plateau is characterized by "hills, hill ranges, rolling lands, interfluves and valleys" (Shiva Prasad et al. 1998: 12f). Climate is generally dry and hot, except during the southwest and northeast monsoon. Average temperatures range from 20° C in winter to 25° C in summer (Mandya District Administration 2014). Southeast monsoon is from June to September with 38% of the average annual rainfall of 699.8 mm. Northeast monsoon is from October to December with 35% of the average annual rainfall. During the winter months of January and February 2% of the total amount of rainfall and in summer from March to May 25% are contributed (Ministry of Agriculture 2011).

The geological formation of the South Deccan Plateau is granite/ gneiss (Shiva Prasad et al. 1998: 5). Caused by hot and dry climatic conditions and eruptive rainfalls during monsoon, soils in Mandya are highly leached and weathered (Ministry of Water Resources 2008). Major soils are i) red sandy loam soils or ii) lateric soils, classified as Alfisols, or iii) medium black soils, classified as Entisols and, iv) red loam soils, classified as Inceptisols (Ministry of Water Resources 2008; Rabidra et al. 1987: 8; Shiva Prasad et al. 1998: 5; cf. figure 6). The potential evaporation exceeds the rainfall almost throughout the entire year hence soil moisture varies between ustic and aridic (Shiva Prasad et al. 1998: 5). Moisture deficit period ranges from 180 to 220 days (Shiva Prasad et al. 1998: 12f).

For these reasons irrigation for cultivation is an important issue in Mandya. 56% of the cultivated area is irrigated and 44% is rainfed area (Ministry of Agriculture 2011). Irrigation is primary dependent on the cauvery canal, which is fed by the Krishnarajasagar dam and reservoir (Amjath Babu 2008: 17; Shiva Prasad et al. 1998: 7). The cauvery river origins from the Western Ghats and flows through the Indian states of Karnataka, Tamil Nadu and Kerala until it reaches the Bay of Bengal (Amjath Babu 2008: 8). Since 800 years water disputes between the boarder states compromise the water security of Mandya (ibid. 2008: 1). At the time of data recording the canal dispute was a topic of discussion, but actual irrigation limitations were mainly caused by current canal work and not by interstate conflicts (oral information from local farmer, 29.10.2014).

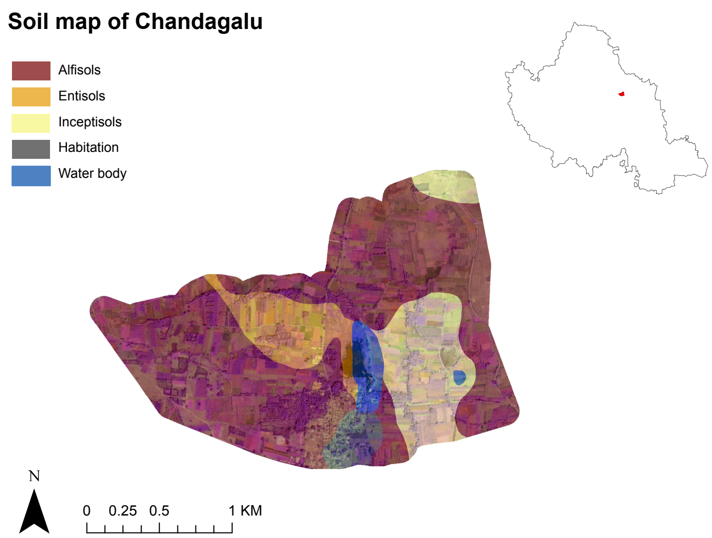

Figure 6: Soil distribution map of Chandagalu (GIS-Data: Agricultural University of Bangalore) (own representation).

Chandagalu counts 3238 inhabitants, whereby the majority is engaged in farming activities (oral information from local Panchayat, 10.10.2014). The main crops that farmers of Chandagalu are cultivating are paddy, sugarcane and ragi. Due to the climatic conditions, the growing period lies commonly between 150 to 180 days (Shivda Prasad et al. 1998: 6f). Whereat paddy and ragi are mainly produced as food crop, sugarcane is a cash crop and is produced to generate income.

Sugarcane is converted to jaggery and/ or sugar, whereby jaggery is produced in jaggery houses located within the village and sugar is produced in the sugar factory in Mandya. In total thirteen jaggery houses are situated in Chandagalu, whereby six of them were in usage (oral information from local Panchayat, 10.10.2014). The other seven jaggery houses stopped running, due to marginal labour availability and decreasing market prices of jaggery. Local market prices for jaggery were decreasing, due to import of jaggery from Uttar Pradesh and Maharasthra (oral information from local jaggery house owner, 12.10.2014). Jaggery is produced, i) by crashing the sugarcane, ii) collecting the juice to clean it by filtering and boiling, whereby the heating is done by bagasse which is the residual material of the sugarcane crushing, iii) and cooling it. The remaining ash from the burning of bagasse is used from the farmers as manure for their field. Jaggery is produced organic or non-organic. In the organic way no additional chemical inputs are used for jaggery production, nor any fertilizer are used in the sugarcane fields (oral information from local jaggery house owners, 09.10.2014).

The sugar factory in Mandya is the main purchaser of the sugarcane produced by the farmers of Chandagalu. "According to the Indian land ceiling act" sugar factories in India cannot own land to produce their own sugarcane (Gobinathan and Sudhakaran 2009: 356). As a consequence sugar factories depend on the sugarcane production from farmers (ibid. 2009: 356). The factory is producing sugar, sugarcane molasses for the conversion to bio-alcohol and uses the bagasse to produce power that is on the one side used to keep the sugar production processes activated (BNDES 2008: as cited in Miranda et al. 2012: 175; Gopinathan and Sudhakaran 2009: 355;

oral information from local sugar factory owner, 29.12.2014). On the other side the conversion of bagasse to energy is highly efficient, hence surpluses are generated, which were fed to the power grid (Gopinathan and Sudhakaran 2009: 356; oral information from local sugar factory owner, 29.12.2014). Within recent years the productivity of the sugar industry in India increased, hence presently it is the second largest agricultural industry after cotton in the country (Gopinathan and Sudhakaran 2009: 356), and after Brazil the second largest sugarcane producer world-wide (Watson 2010: 5746). However as Gopinathan and Sudhakaran (2009: 357) illustrate, the increase “growth in area and productivity” remains not stable over longer terms. Natural factors, such as climate conditions of “flood and droughts, pests and diseases” and socio-economic factors, such as fluctuations in prices of local sugar products, governmental policies regarding the sugarcane price, mechanism taxes and export and import controls are resulting in circular fluctuations of sugarcane prices on the market (Gopinathan and Sudhakaran 2009: 357) and hence are influencing farm management decisions and livelihood securities of farmers.

Within the village one household uses one biogas plant, whereby seven biogas plants have been installed, but were stopped operating (oral information by local Panchayat, 10.10.2014). Biogas plants have been first installed in the seventies in rural India to meet the growing energy demand (Gopinathan and Sudhakaran 2009: 352). Before the energy demand for cooking has been covered by wood, but caused health problems “due to indoor pollution” (ibid. 2009: 352), hence biogas plants were thought on the one side to prevent deforestation and on the other side to reduce the risk of health problems. Biogas plants convert compost and dung to gas, which is used for cooking. The remaining solid material, called slurry, is further used as manure and is put to the field (Gwavuya et al. 2012: 202). In India 3.7 millions biogas plants, most of them were subsidised, were installed, but only half of these are presently in use (Gopinahtan and Sudhakaran 2009: 352). In other countries of development contexts, such as Ethiopia, the same pattern can be observed. 60% of biochar plants that have been installed stopped functioning “due to water and dung shortages, technical problems, abandonment and loss of interest” (Gwavulya et al. 2012: 203). Gwalvulya et al. (2012: 202) indicates, that reasons of abandonment depend on the efficient use of slurry as a source of fertilizer and on the price of the replaced energy source. In present time in rural India most of the farmers have access to energy sources, such as liquefied petroleum gases, hence interests in using biogas plants for energy supply were low (oral information from local farmers, 11.10.2014).

Within Chandagalu a Panchayat is located, which locally represents the government. The local Panchayat is responsible for providing social services as well as agricultural services to the community. Close by, located in Mandya, the VC farm, an Agricultural College is as well providing help for agricultural matters (Mandya District Administration 2014).

4.2. Manoor

Manoor is located in the district of Udupi (13°12'30" N, 74°41'0" E) within the West Coast Plain region. This region is situated on the west coast of Karnataka between the Arabian Sea and the Western Ghats, therefore Udupi and hence Manoor is located close to the sea. The geological unit of the West Coast Plains is gneiss (Ministry of Water Resources 2008). Geomorphological the area is divided into two different areas, whereas the hinterland is characterised by west-flowing streams and lateralization, the low-level coastal plain where Udupi district and Manoor are located, is characterised by fluvio-littoral formations and ironstone crusting (Shiva Prasad et al. 1998: 3f). The climate is humid-tropic with an average temperature of 27° C that varies 3.5° C throughout the year (Climate-Data 2014). Climate is characterized by the monsoon periods (Shiva Prasad et al. 1998: 5), hence the annual average rainfall measures 3728 mm (Ministry of Agriculture 2011) and the annual average humidity is 78% (Udupi District Administration 2014). The monsoon periods divide the year into four seasons. During the southwest monsoon season in the months of June, July, August and September 88% of the annual rainfall is contributed. The months of October and November in the season of the northeast monsoon are mostly warm and humid, in December it rains 7% of the annual rainfall. Winter starts in January, lasts until end of February and is generally dry and cool, whereat in summer season from March until May climate is hot. In summer it is raining the last 5% of the annual rainfall (Ministry of Agriculture 2011; Udupi District Administration 2014).

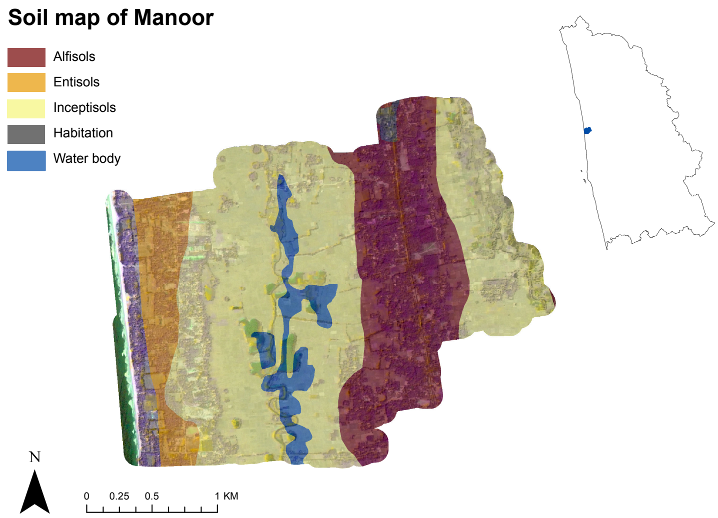

Figure 7: Soil distribution map of Manoor (GIS-Data: Agricultural University of Bangalore) (own representation).

The geographic location and hence the geologic, geomorphologic and climatic conditions of the West Coast Plain determine the local soils and the local agricultural productions. Soils types are mainly influenced by the climate conditions, hence soil moisture is generally high (Shiva Prasad et al. 1998: 5) during monsoon seasons, but low to non-existent in summer. The potential evapotranspiration exceeds rainfall from November to April, hence there is a moisture-deficit in soil for about 150 days (Shiva Prasad et al. 1998: 40). Soil types as well differs according their geomorphological conditions. Soils of coastal plains, either are i) sandy soils, which are deep, sandy and imperfectly to poorly drained, or ii) yellow loamy soils, which are deep, sandy over loamy stratified and imperfectly drained. Those soils are classified as i) Entisols or ii) Inceptisols, depending on their formation of horizontal differentiation (Shiva Prasad et al. 1998: 46; Ministry of Water Resources 2008; cf. figure 7). Major crops grown in areas with those soils are rice, groundnut, pulses and coconut. Caused by the proximity of the sea and the hot and dry temperatures in summer agriculture is complicated by salinity, a high water table, poor drainage, and sandy soil texture (Shiva Prasad et al. 1998: 46). In the upper land Alfisoils are dominating. Those soils, such as red lateric soils are moderately shallow to very deep, well drained to excessively drained, gravelly clay soils (cf. figure 7). The major crops grown in that area are arecanut and coconut. The major constraints are salinity, ironstone crusting, moderate to severe erosion, low bases and low nutrient status (Shiva Prasad et al. 1998: 40).

Within the region of Udupi 33% of the cultivation area is irrigated, 67% is rain-fed area (Ministry of Agriculture 2011). This situation is similarly in the village of Manoor. Accordingly to administrative data no water facility is located within the village. At the time of visiting at least one of 17 farmers, which were interviewed, has built a well and a pipeline in order to irrigate his field (oral information from local farmer, 22.10.2014). The length of growing period of this region is denoted by 240 to 270 days (Shiva Prasad et al. 1998: 6), hence is longer than the growing period of Chandagalu. Caused by the proximity of the sea, not only agriculture, but also fishing is an important engagement of the 6381 inhabitants distributed over 1042 households in Manoor (oral information from local Panchayat, 21.10.2014).

In Manoor 50 biogas plants are constructed, but 20% of them were shut down (oral information from local Panchayat, 21.10.2014). According to information of the Kota Panchayat, 25% of the farmers are using ash as manure (oral information from local Panchayat, 21.10.2014). The ash is provided by the local rice mill or by the fish factory. Fish factories in this region use the remaining rice hull husk of the rice mills for fishmeal production and provide the local farmers with the remaining ash (oral information from local fish factory owner, 05.12.2014).

Udupi taluk is the governmental administrative division to which Manoor belongs. Panchayat Kota is a subdivision of the Udupi taluk and represents the government locally. Udupi and Kota are the next larger cities close-by Manoor. In these two cities are also the rice mills located, which are the main buyers for paddy. Within Kota a RSK, a governmental supported agriculture extension service is located, providing the inhabitants of Manoor with information about the governmental schemes and technologies that are available (Karnataka State Department of Agriculture 2007).

5. Methods

Data assessment and analysis followed a circular procedure in order to systematically complement and confirm/ triangulate the results. This corresponds with the grounded theory approach, which is characterized as an inductive-deductive way of the development of theories that represent reality as close as possible (Strauss and Corbin 1996: 39). A traditional grounded theory approach is iterative, thus data is sampled and analysed continuously, based on its empirical findings (ibid. 1996: 40). In this study this procedure was slightly modified, hence data assessment and analysis founded on a predefined "sensitizing conceptual framework" (cf. chapter 4; Witzel and Reiter 2012: 106). This different way of data assessment and analysis was chosen to determine the relevant analytical scope, because the examined phenomenon is hypothetical, thus none of these villages has implemented a biochar system so far.

As illustrated in chapter 4.5 the utilised "sensitizing conceptual framework" for this study is based on the theoretical concepts of socio-ecological resilience and social differentiated vulnerability. By determining these characteristics of a system and of individuals it is supposed to derive adaption barriers and hence indicate a sustainable way of an implementation of a biochar system into the sugarcane and/ or the rice production circle of Chandagalu, respective of Manoor. In order to make these theoretical concepts tangible, two analytical frameworks were selected. For a determination of resilience of a system, the approach of an interrelated socio-ecological system and for a determination of individual vulnerability the sustainable livelihood approach was chosen.

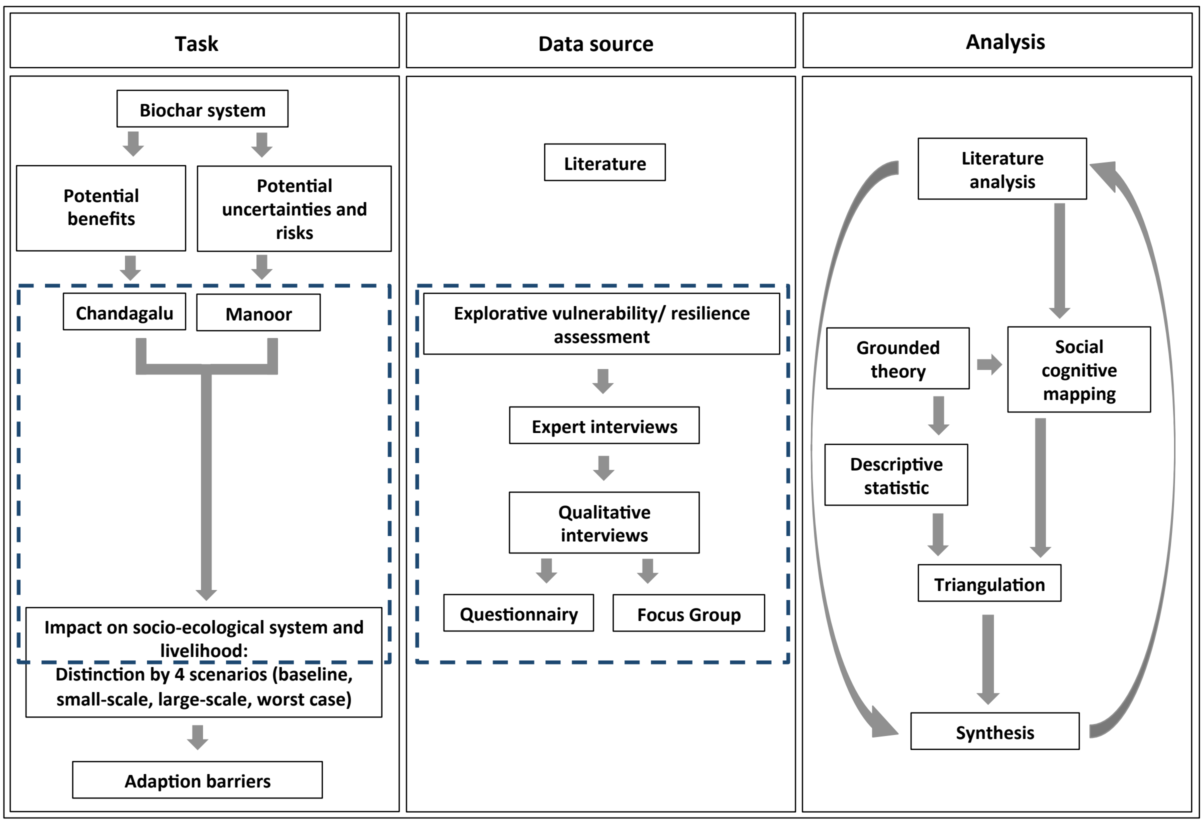

Figure 8: Visualisation of data assessment and data analysis (own representation).

The process of an identification of adaption barriers based on the resilience of a socio-ecological system and the vulnerability of its individuals was guided by three main tasks (cf. figure 8): i) identification of biochar system benefits, potential uncertainties and risks, ii) determination of the impact of a biochar system on the resilience of the socio-ecological system and on the vulnerability of the individual livelihoods, and iii) identification of adaption barriers. The first task was met by a literature review (cf. chapter 2). The second task involved two sequenced data assessments and three sequenced data analysis. A first data assessment was completed by expert interviews and qualitative interviews with farmers. Data of the first assessment was analysed a first time by using the grounded theory approach. Based on this analysis a second data assessment was conducted. The seconded data assessment involved a questionnaire and focus groups with students and farmers. Afterwards, data of the first assessment was analysed a second time, using a grounded theory based method, named cognitive mapping to determine the baseline resilience of the socio-ecological systems and the vulnerability of the individual livelihoods. Within this cognitive map a hypothetical biochar system was implemented, in order to determine small-scale and large-scale implementation scenarios and their impact on resilience and vulnerability of the socio-ecological system and the individual livelihoods. These results were complemented by analysing the questionnaire of the second data assessment, using descriptive statistics to identify the outcome of a worst-case scenario. The last task was fulfilled by analysing the results of the baseline-, small-scale-, large-scale-, and worst-case-scenario and was complemented and confirmed by the results of the focus group, which were analysed using qualitative content analysis.

The following sections provide a deeper insight into the different methods, which were used for data assessment and data analysis. The illustration starts with a section about the first data assessment, thus the theoretical background of expert interviews and qualitative interviews, how these methods where applied and how they were analysed in order to use these first results for the second data assessment. The theory and practical realisation of these second data assessment, applying a questionnaire and focus group, accordingly are presented in the second section. A third and terminal section explains the second data analysis, thus how the cognitive mapping method was applied, how the different scenarios were created and how the questionnaire and the focus group were analysed.

5.1. First data assessment

The first data assessment took place in October 2013 in the state of Karnataka, South India. Two methods were applied: i) expert interviews and ii) qualitative interviews with farmers.

5.1.1. Expert interviews

Expert interviews are suitable especially during the first approach of a research theme, where structure and information are not concretely defined. Expert interviews are an efficient way to conduct relevant data, insider knowledge, which would otherwise take more effort to obtain and equips the researcher with relevant pre-knowledge for further steps of data acquisition (Bogner and Menz 2002: 7; Locatelli et al. 2008: 9). Moreover the data analysis of the results of the expert interviews can be used later on for additional triangulation in order to complete and confirm the acquired results (Shih 1998: as cited in Foss and Ellefsen 2002: 244).

For these reasons, right at the beginning three expert interviews with two local soil scientists and one agricultural economist of the Agricultural University of Bangalore were conducted, in order to obtain general information about the social, economic and ecological values of agriculture in India and more specific inside knowledge about potential biochar system implementations in Karnataka, thus several experimental field studies with the use of biochar as a soil amendment have been conducted so far within the University context. This data primarily has been used to refine the scope of research, but as well has later been used for triangulation. Likewise scientists have been inquired to mark on a map of Karnataka the most suitable regions and to explain their choices, in order to select a suitable research area. Based on this information, agro-climatic conditions and provided accessibility the research area has been chosen.

On-site further expert interviews with local soil scientists have been conducted. This time more specific information about the agricultural situation in the specific region of visit was asked for, in order to select a suitable village and to obtain data for further triangulation. For a better understanding of the livelihood contexts of the farmers additional expert interviews with two rice mill owners, one sugar factory and two jaggery house owners and as well with an owner of a fish factory have been conducted.

Expert interviews have a rather explorative character; hence the interview outline is pre-structured to a certain extent. Questions for relevant topics insofar have been phrased, but divergences of the prepared outline during the interview are allowed and necessary in order to obtain a relevant depth of the addressed topics. This approach has the advantage that it allows the interviewer to guide the interview according to the specific knowledge of the experts, but has the disadvantage that the interviewer has to have a certain kind of flexibility. Likewise the quality of results depends on the pre-knowledge of the interviewer, thus the more pre-knowledge is existing the better an interviewer might respond to and deepen the relevant topics.

5.1.2. Qualitative interviews

The emphasis of this research work lies especially on the consideration of local farmer's knowledge regarding an implementation of a biochar system. To assess farmer's knowledge individual interviews were conducted. Individual interviews are especially suitable to reveal "socially sensitive topics" (Kaplowitz 2000: 427), thus suitable to examine livelihood activities and their constraints. Interviews were semi-structured and designed according to the principles of "problem-centred interviews".

The term "problem-centred interviews" describes a qualitative method that is characterized by its deductive and inductive interrelation (Kurz et al. 2007: 465; Witzel 2000: 3). A problem-centred interview is deductive in the sense, that it is guided by a sensitizing conceptual framework (Witzel and Reiter 2012: 106), and inductive, that it seeks to be impartiality in order to be open for "individual actions and subjective perceptions" (Witzel 2000: 2). The emphasis is to identify the inner concept of the problem of interest that is owned by the respondent. Accordingly, pre-knowledge about the theoretical concept of the problem of interest is necessary, in order to keep the focus, but the interview is guided in a way that leaves space for subjective interpretations, perceptions and opinions regarding the problem of interest (Witzel 2000: 2).

The interview guideline for a problem-centred interview is semi-structured and is composed by four different kinds of questions: i) introductory question, ii) questions for sounding, iii) ad-hoc questions and iv) questions to improve understanding (Witzel 2000: 6). These questions serve as a guideline and support for the interviewer to focus on the problem of interest, but as well can be adapted during the interview. Furthermore, a certain structure enables a comparison between the data during data analysis (Hölzl 1994: as cited in Kurz 2007: 465).

By applying a problem-centred interview method, the selection of respondents is likewise guided by the sensitising conceptual framework, thus is deductive. For this study a maximum variation strategy or a purposeful sampling method was applied (Patton 2006: 1366). Respondents were selected based on their point of contact concerning the problem of interests. While sampling, attention was payed to select different kinds of farmer with variations of age, gender and property, in order to achieve a wide range of different livelihood activities. In most cases after a first establishment of a contact with a particular person of interest, other respondents, which conform relevant characteristics concerning the problem of interest, were accessible by the “snowball effect” (Kurz et al. 2000: 468).

In this study in total 42 interviews with the help of a translator were conducted: 24 in Chandagalu and 18 in Manoor (cf. annex D). The interview was devided in three parts. The topic of the first part was about the general livelihood of the farmers. The second part was more specific about their experiences with technologies, such as biogas plants and the third part was about a biochar system and how an implementation might concern their livelihood. For the third part the function of a biochar system was explained. Hereby a schemata and pictograms were used to explain the function and as well the potential benefits of a biochar system (cf. annex C). The composition using three different parts was chosen, because of the intention to receive unbiased responses for the first two parts. However the central aspect in each part was the livelihood of the farmers, their level of vulnerability and their experiences with agricultural technologies. The focus or problem of the interview thus can be described be the following three questions:

i) What are general and specific exposures (hazards, perturbations, stresses) regarding agricultural technologies?
ii) What strategies were applied by the farmers to deal with those general and technology-specific exposures?
iii) What are sensitive elements within the systems regarding general and technology-specific exposures?

The first part of the interview was overall highly informative, thus farmers enjoyed talking about their life and their concerns. The second part was partly successful, hence farmers who made experiences with a biogas plant were motivated to speak more deeply about their opinions and perceptions about the moderate successful implementation of biogas plants (cf. chapter 5). The focus of the interview was turned quicker to overall experiences with technologies during interviews with respondents having no experiences with biogas plants. In the last part, the implementation of a biochar system regained farmers’ attention. The prepared schemata and pictograms have been a success, thus farmers understood easily what the topic was about.

All interviews were conducted with the help of a translator. The translation of the respondent’s answers was not word-by-word, the translator moreover translated a summary of the answers of the farmers, in order to interrupt the fluency of speech as less as possible. This carries the risk that important nuances of the respondents were not possible to capture by the interviewer. Likewise the translation process needed time and unintended interrupted certain narrations of farmers. Consequently, the interviewer was constraint in his/ her capability to ask adequate questions, which might intensified certain relevant aspects concerning the problem of interest. During the interviews it happened several times, that the interviewer was asking questions about certain aspects to illuminate their relevance, which the respondents already mentioned in previous sections of the interview, but were not directly translated by the translator, which sometimes led to a certain confusion between interviewer, translator and respondent.

Per definition a problem-centred interview is conducted with a single individual respondent. However in most interviews more than one person were attending the interview. Since this was not possible to avoid, it was allowed, thus in the most cases additional family members were joining and as such were creating a familiar atmosphere, in which respondents seemed to feel comfortable.

5.2. First data analysis

The qualitative interviews with farmers were analysed a first time using the grounded theory method. Based on these first results the following second data assessment was prepared.

5.2.1. Grounded theory

Grounded theory is a methodical and analytical procedure for a systematic development of a theory, which represents reality as close as possible (Strauss and Corbin 1996: 39). Grounded theory is characterised by its deductive and inductive procedure used for data sampling and data analysis (ibid. 1996: 41). In the grounded theory method, data sampling is theoretical. This differs to the problem-centred method, where data sampling is mostly purposeful (Witzel and Reiter 2012: 61). Theoretical sampling is iterative, thus sampled data is analysed continuously and based on its theoretical or empirical findings additional respondents were selected (Strauss and Corbin 1996: 40). This iterative procedure continues until a theoretical saturation is reached; hence no new findings about a phenomenon were possible (Witzel and Reiter 2012: 61). Samplings of problem-centred interview contrary are problem-oriented, in a sense, that respondents were selected purposeful, in order to illuminate best possibly all problem relevant aspects (Patton 2006: 1365).

Theory generation in grounded theory is based on three central methods: coding, conceptualisation and categorisation (Bernard 2002: Isaac et al. 2008: 1322). These three methods are applied in three distinguishable forms of analysis: open, axial and selective" analysis (Witzel and Reiter 2012: 101). Open analysis refers to the "process of breaking down, examining, comparing, conceptualizing, and categorising data" (Strauss and Corbin 2006: 43; Witzel and Reiter 2006: 101). Text data accordingly is iteratively analysed by naming or coding different phenomenon and dimensioning these phenomenon's by comparing other text data that describe the same phenomenon. The result of this dimensioning is a concept that refers to all characteristics mentioned in the text data, which are describing the phenomenon (Strauss und Cordin 1996: 43). All derived concepts are further summarized in categories. Axial analysis utilizes these categories and joins them back together by setting them into relation (ibid. 1996: 76). These relations are determined by using a causal model, which examines the "context, causal conditions, interventioning conditions, strategies of action and interaction, and consequences of action" of each category (ibid. 1996: 78; Witzel and Reiter 2006: 106). Based on this relationing a development of first interpretative hypotheses and a selection of "core categories" are possible (Witzel and Reiter 2012: 101). Selective analysis finally reviews text data in order to deepen the interpretative hypothesis resulted from axial coding. Text data is analysed with the focus of "systematically relating" the "core category" to other categories, "validating those relationships, and filling in categories that need further refinement and development" (ibid. 2012: 101).

For the preparation of the second data assessment, the data of the qualitative interviews were transcribed and coded manually by using the open-access coding program TAMSanalyzer. The open coding process was guided by the identical questions that framed the focus of the interviews (cf. chapter 6.1.2.). The derived concepts were summarised in categories, which were pre-defined by the sensitizing framework of vulnerability, defined in the beginning of research: i) exposure; ii) sensitivity, and iii) strategies. For a validation of these first results, a standardized questionnaire was developed, which is described in more detail in the following section.

5.3. Second data assessment

Based on the results of the first data analysis a second data assessment was conducted. The second data assessment took place in November and December 2013 likewise in the state of Karnataka, South India. Within the second data assessment a questionnaire and five focus groups were conducted.

5.3.1. Standardized questionnaires

An implementation of a biochar system is not accompanied without uncertainties and risks, which potentially alter the resilience of a socio-ecological system and increase the vulnerability of the people. The relevance of an occurrence of risk regarding a biochar system however is dependent on how the individuals experience the risk. This experience dependents on their exposure, sensitivity and adaptive capacity to this harm. By analysing the first data resulted from the "problem-centred interviews" a set of perturbations where identified which negatively influence the livelihood of the farmers. Based on previous literature research about potential uncertainties and risks of an implementation of a biochar system, a selection of biochar system specific perturbations were chosen, which might reinforce current system-specific perturbations. For a comparison of both villages, solely perturbations that occur in Chandagalu as well as in Manoor were selected. These are: "no good yield", "youngsters move to the city", "labours problems", "health costs", "unsuitable governmental schemes", "soil gets spoilt", "costs of fertilizer and manure are increasing" and "unsuitable technology". "No good yield" refers to production and application uncertainties, which influence the characteristics of a biochar and thus influence the outcome, respectively the final yield. "Youngsters move to the city" and "labours problems" are referring to the needed human resources for a successful implementation of a biochar system. "Health costs" are referring to the potential negative effect to human health, caused by production emissions or fugitive loss of biochar during transportation. "Unsuitable governmental scheme" and "unsuitable technology" are referring to the needed trust in institutions that are responsible for knowledge and technology transfer. "Soil gets spoilt" is referring to the potential risk of an incorporation of contaminants into the soil or phytotoxic effects caused by a biochar application and "cost of fertilizer and manure are increasing" is referring to a successful biochar application, which is interlinked with fertilizer and manure additions.

Using these first results of the analysis of the "problem-centred interview" data, a standardized questionnaire was developed (cf. annex E). For each perturbation farmers were asked to weight them according their relevance for their livelihood. Additionally weightings had to be differentiated between a scenario where profit is possible and a scenario where profit is not possible to make. Profit in this sense is linked with a successful implementation of a biochar system or with stable market prices. Accordingly the following two hypotheses were tested:

i. all selected perturbations influence the livelihood negatively
ii. if no profit is possible the impact on the livelihood of certain perturbations are higher, than in cases where profit is possible[2]

[2] An implementation of a biochar system could potentially reinforce those perturbations negatively. However in cases were profit is possible to generate with an implementation of a biochar system or were market prices are stable, the impact of exposures is less.

Further farmers were asked about their opinions about reasons for the occurrence of such perturbations and their strategies how they manage these perturbations.

In total 54 questionnaires were conducted with the help of a translator. In Chandagalu eight local students and in Manoor two RSK employees helped conducting the questionnaire. In Chandagalu 28 questionnaires were conducted, whereupon five of them during a pre-test. In Manoor 26 questionnaires were conducted. Gender and age of respondents were mixed. In Chandagalu 13 female and 15 male and in Manoor 17 female and 9 male respondents were answering the questionnaire. In Chandagalu 11 persons were between 20-35, 13 persons between 35-50 and four persons more than 50 years old. In Manoor six persons were beween 20-35, seven persons between 35-50 and 13 more than 50 years old. The questionnaires were conducted together with the focus group. Results of questionnaires were collected and tabulated into an excel-sheet for further analysis.

The initial purpose of the questionnaire has been an extensive coverage of both villages Chandagalu and Manoor to generate representative results. The pre-test revealed, that the design of the questionnaire was not appropriate for a large sampling. On the one hand the required time to complete a questionnaire was underestimated and on the other hand the farmers did not understand the scenario-based questions properly. The questionnaire thus was adopted and distributed during the focus group.

5.3.2. Focus Group

A focus group can help “to better understand how people feel or think about an issue […]” (Krueger and Casey 2000: 4). This assumption origins in a constructivist view of reality, in which reality is understood as a social construct and not “independent from human interactions” (Kamberelis and Dimitriadis 2013: 3). Attitudes and opinions of people accordingly are socially formed (Breen 2006: 467). A focus group sets up a social context in which individuals have to interact and interchange opinions with each other (Breen 2006: 467). This is different to individual interviews were “the respondent is limited by the choices offered” from the interviewer (Krueger and Casey 2000:5). Results of an individual interview accordingly could be “unintentionally influenced by the interviewer through oversight or omission” (ibid. 2000: 5). Within a focus group setting the interviewer is changing his role to a moderator. A moderator is guiding the conversation, asks questions, listens and makes sure that everyone has the change to share (ibid. 2000:9). This differs to the individual interview setting, where the discussion is dominated by singular attitudes or opinions either those of the interviewer or respondent. Opinions and attitudes in focus groups discussions moreover were questioned and criticised which makes focus groups especially suitable to “reveal multiple aspects” and to broaden the view of a particular problem or a solution of a problem (Breen 2006: 466; Kaplowitz 2000: 428).

Within a decision-making context as such, whether a biochar system implementation in Karnataka is appropriate or not, a focus group can help to refine the knowledge about the social context where an implementation will take place, in order to evaluate adaption possibilities. A focus group as well might complement previous findings, thus it can broaden the view of the extent of the topic regarding potential benefits, constraints and solutions. For this study in total four focus groups were conducted. One focus group was conducted with soil science and agricultural economic students of the Agricultural University of Bangalore, two focus groups with farmers of Chandagalu and two focus groups with farmers of Manoor. In traditional focus group settings solely focus groups with participants of the same social or institutional affiliations were legitimate to compare (Krueger and Casey 2000: 4), because results of focus groups are “very context-specific and therefore not generalizable to other institutions or contexts" (Breen 2006: 467). However for this study a "broad-involvement design" was chosen, because farmers in this case were defined as "target audience" - an audience who is considered to be the greatest information-rich source, whereas other sources, in this case the students, were providing secondary, complementary perspectives (ibid. 2000: 33). Hence results of the focus group with students were not directly compared with results of the focus group with farmers. The former results moreover were used to complement and refine the latter.

5.3.2.1. Focus group with students

Based on the first results of the expert and qualitative interviews a focus group was conducted at the Soil Science department of the Agricultural University of Bangalore. The focus group was consisting mainly of soils science and agricultural economic students, either master or PhD students (n = 15 $^{+}$/- 3). The aim of the focus group was to obtain perceptions and opinions about social, economic and ecological constraints and potential solutions regarding an implementation of a biochar system in Karnataka. Most agricultural students of the Agricultural University of Bangalore are completing a village stay during their bachelor studies, where they spend several weeks living and working together within a farming based community. Accordingly students not only have a strong theoretical background on agriculture, they as well have a practical background, allowing them to consider multiple perspectives about farming and a potential implementation of a new technology, such as a biochar system.

First an introduction of the topic was given in form of a presentation, where the aim of the focus group, background information about a biochar system and first results of the study were given. To give the students time to get familiar with the topic, eight different scenarios of possible implementations of a biochar system were presented (cf. annex F). The focus group members accordingly were divided in eight groups, in order to discuss the following questions:

i. With your knowledge as soil scientists, what are the effects biochar would have on good or low quality soils in dry/ wet climatic conditions?
ii. How would a biochar system implementation on a small/ large scale improve the livelihood of the farmers?
iii. In which point do you see difficulties of an implantation of a biochar system on a small/ large scale?

The results of these small group discussions were sampled and further discussed within a big round. To equally integrate social aspects, provoking statements of farmers selected from the qualitative interviews part were mentioned during the discussion.

Overall the focus group discussion fulfilled its purpose, thus students were providing interesting complementary findings. But the focus group discussion was not without any difficulties. At the beginning the flow of discussion was difficult to activate, manifesting in a one-to-one discussion between a student and the moderator. This was the case, because the purpose of the focus group discussion was not clear, although it was mentioned in the beginning of the presentation. The focus group took place just after a series of student presentations, whose results were defended afterwards. Accordingly, the focus group members were reacting the same way, asking critical questions about the presented first results of the study, then discussing among themselves about their perceptions and opinions about an implementation of a biochar system. This incident might be prevented by first asking directly every student about his or her opinions, than directly focusing on the "key questions". Likewise it would prevent the domination of one single focus group member to guide the discussion (Breen 2006: 467), which is contra-dictionary to the proper aim of the discussion, which is the disclosure of socially constructed perceptions and opinion. Inputs to provide these incidents are provided by Krueger and Caseys (2000: 44). They propose the usage of five different types of questions, i) opening question, ii) introductory questions, iii) transition questions, iv) key questions, v) ending question. These questions help to keep the focus and flow of the focus group discussion.

5.3.2.2. Focus group with farmers

Two focus groups with farmers were conducted in Chandagalu and two in Manoor. Each time 12 $^{+}$/- 2 farmers were attending the discussion. One focus group discussion in Chandagalu was placed within a park next to the panchayat of the village and the other one in the garden of a farmer's house. In Manoor focus groups were placed inside a house and outside on a veranda. The purpose of the focus group with farmers was to identify constraints and potential solutions regarding an implementation of a biochar system. The major difficulty of assessing the perceptions and opinion of the farmers regarding an implementation of a biochar system was that the topic of interest was hypothetical, thus no biochar system exist in those villages. Due to that matter a trans-disciplinary approach was chosen. Accordingly, for the introduction into the topic of this study, a different approach was used than for the students. Instead of a presentation with figures and numbers a "trade-off game" was played with the farmers (annex G). In Chandagalu eight students were helping to explain the rules of the game and documenting the results. Within two sessions, the game was played each time within four groups. Every group was counting four to five farmers and were assisted by a student. In Manoor the trade-off game was played two times within a bigger round of six people.

The trade-off game should simulate an investment decision scenario. Farmers could choose their initial farm setting, such as soil, crop and irrigation type, as well family members and amount of savings [income - expenses] after one year. In round one the benefits and costs of a biochar system were explained and each farmer could decide if he or she wants to invest individually or collectively in a biochar system. An individual investment consequently resulted in higher initial costs, but as well in more benefit after one year. A collective investment otherwise resulted in lower initial costs, thus costs were shared, but as well in less benefits for each one, as for an individual investment. Likewise farmer could choose to take a loan, if their initial savings were too low or due to other causes. However like in real live they were indicated to pay the loan back in the following years.

Round two was situated one year later. Accordingly the situation of the farmers changed. This change was represented by two different kinds of "event-cards". One staple of "event-cards" represented the change for everyone, and the other individual change. "Event-cards" that changed the situation of everyone similarly, were either impacting market prices positively or negatively. In cases of a positive impact all farmers received an additional amount to their savings generated after one year. In cases of a negative impact farmers received less savings than they had declared in the beginning. Individual "event-cards" were taken by each farmer separately. These event cards described different scenarios, such as "bad yield", "good yield", "youngsters are moving to the city and labours are needed", "wages for labours increased", "illness", "fertilizer costs increased", "governmental scheme", "soil gets spoilt" or "everything stays the same". Each scenario was associated with costs or benefits. Consequently savings of each farmer decreased or increased.

After simulating changing conditions, farmers which invested into a biochar system or which took a loan in the first round received their benefit, or respectively had to bay back a part of the loan. Then each farmer was asked again, if he or she wants to invest in a biochar system individually or collectively. Likewise, they could choose to take a loan. Playing another round, the discussion based on the results of the trade-off games, was started.

The discussion started by asking every farmer why he or she decided to invest or not invest into a biochar system. The following discussion was guided by these three main questions:

i. What are the conditions that do not allow an investment?
ii. What are the reasons for such conditions?
iii. How the conditions should be different, that you would have made an investment?

The process of conducting these four focus group discussions with the farmers revealed similar to the focus group with students, that an organisation and realisation of a focus group discussion is more demanding for the researcher, respective the moderator than a conduction of an individual interview. This might be explainable because perturbations within a focus group discussion are more difficult to predict or to control. Similar to the individual interviews with farmers, other people showed up and were asking questions about the purpose of the focus group. One focus group was surprised by heavy rainfall, leading farmers to go back home. The second focus group in Manoor was stopped after playing the game, because farmers had to go back to the field. The evaluation of the trade-off game as method to illustrate the farmers the function of a biochar system is difficult to obtain. Comparing the outcome of both villages, the focus group discussion within Manoor appears to be more focused on the proper topic than the other two focus group discussions in Chandagalu. In Chandagalu the discussion moreover confirmed previous difficulties of the farmers regarding their livelihood, than focusing on the suitability of an implementation of a biochar system. This might be explainable due to the matter that the trade-off game in Chandagalu was assisted by students and in Manoor the researcher; respective moderator was attending the game. Accordingly, questions of farmers could directly be answered and likewise reasons for decisions could directly be inquired.

5.4. Second data analysis

Different methods require different analysis approaches. The analysis of the qualitative data resulted from the problem-centred interviews with farmers of Chandagalu and Manoor were analysed a second time, likewise basically guided by grounded theory, but applying a cognitive mapping to identify relevant aspects without loosing the richness of data (Eden 1994: 264). The questionnaire were analysed using descriptive statistics and data resulted from the focus group discussions was analysed using qualitative content analysis.

5.4.1. Cognitive mapping

The cognitive map method origins in graph theory, “which started with Euler in 1736” (Biggs et al. 1976: as cited in Özesmi and Özesmi 2004: 45) and was first utilized in social science in 1967 by Axelrod (Vanwindekens et al. 2014: 1), who used these principles of graph theory to visualise a social system. He used “information from the public” and represented this information as a network of nodes and directed edges to show casual relationships and called those representations “cognitive maps”, as they visualise an external representation of an individual’s internal perception of reality (Gray et al. 2013: 2; Vanwindekens et al. 2014: 1). Cognitive maps thus are directed graphs - a network of nodes and directed edges - that represent the causal relationships (Vanwindekens et al. 2014: 1) of elements within a system, based on individual perceptions of reality.

The method of creating cognitive maps of individual's perceptions of reality, were used in various application areas. Eden (1994) used the method for problem solving in organisations. A cognitive map in his understanding, is "designed to help depict the structure of a problem", because a cognitive map includes both, "a description of a problem situation and […] an understanding about what can and cannot be done about a problem" (Eden 1994: 264). Others (Özesmi and Özesmi 2004; Özesmi 2006) applied the method in sustainable ecosystem management. A conservation program might only be accepted by the local population, if "it does […] originate from their own perceptions" of how the system is or should working (Özesmi 2006: 1). Developing a cognitive map of the perceptions of local stakeholders might help to detect not solely how the "given system operates" (Özesmi and Özesmi 2004: 44), as well it can help to define suitable policy options that involves local understanding and knowledge about the value and usage of the particular ecosystem (Özesmi and Özesmi 2004: 44; Özesmi 2006: 1). Isaac et al. (2008) and Vanwindekens et al. (2014) used the method to understand farm management decisions. A cognitive map can help to "gain insights into how farmers think their production system works" (Fairweather 2010: as cited in Vanwindekens et al. 2014: 1) and to "determine mechanisms driving farmers preference […] in farm management" (Isaac et al. 2008: 1321). This understanding in return can help to develop sustainable farm management recommendations (Isaac et al. 2008: 1321). Murungweni (2011: 14) similarly analysed decision makings of farmers, but expanded the scope of analysis to the entire livelihood activities of a farmer and how these livelihood systems change under specific impacts. As well Rajaram and Das (2010) were interested in farming based communities. In their analysis they used a cognitive map to identify the relationship between farmers livelihood activities, their impact on the environment and contrarily the influence of a changing environment on livelihood activities of the farmers. Their frame of analysis consequently was a coupled socio-ecological system (Rajaram and Das 2010: 1734). Gray et al. (2013) otherwise used cognitive mapping to define problems that hinder adaptive action regarding climate change impacts. They used perceptions of climate vulnerability of local stakeholders of a coastal area to build a cognitive map in order to understand their logic of decision-making (ibid. 2013: 1).

The cognitive mapping method accordingly is especially appropriate for decision-making processes involving complex relationships within social and/ or socio-ecological systems. A cognitive map can capture and link different concepts or ideas of a particular problem or system, due to its unlimited complexity and flexibility (Özesmi and Özesmi 2004: 45). Especially in cases were precise scientific data is lacking and relationships between elements of a system are not known with certainty (Özesmi and Özesmi 2004: 43; Isaac et al. 2008: 1321), or were a solution for complex problems with several parties involved have to be worked out (Özesmi and Özesmi 2004: 43) a cognitive map can help to better understand uncertainties and complex, dynamic relationships in an organised and structured manner (Isaac et al. 2008: 1323). Furthermore the method is especially suitable to insert local knowledge into decision-making processes (Isaac et al. 2008: 1321). In a decision-making context, where the local population is affected a so called bottom-up or participatory approach is crucial. A cognitive map can not only involve their specific knowledge it can as well serve as a communication foundation for further planning steps. (Murungweni 2011: 14)

Based on these reasons the cognitive mapping method was applied for the analysis of the qualitative data resulted of the problem-centred interviews with farmers of Chandagalu and Manoor. Two cognitive maps were developed, one representing the socio-ecological system where the farmers of Chandagalu are managing their livelihood, the other representing Manoor. The cognitive mapping procedure was based on the different cognitive mapping approaches described above (cf. Eden 1994; Gray et al. 2013; Isaac et al. 2008; Özesmi and Özesmi 2004; Özesmi 2006; Rajaram and Das 2010; Vanwindekens et al. 2014). The following section explains in detail how these cognitive maps were created:

i. All transcribed interviews were coded using AtlasTi by asking the following questions:
   - What are general and specific exposures (hazards, perturbations, stresses) regarding agricultural technologies?
   - What strategies were applied by the farmers to deal with those general and technology-specific exposures?
   - What are sensitive elements within the system regarding general and technology-specific exposures?

ii. This first open coding resulted in 341 concepts in Chandagalu and 512 concepts in Manoor. All codes were separately aggregated and categorized. The aggregation was based on the pre-defined sensitizing conceptual framework and guided by the following question:
   - What are the defining assets that structure the livelihood of farmers within their community?

   An aggregation in this sense aggregates all codes that are similar to or are related with each other. The specific assets accordingly were not predefined based on theory, assets were identified inductive, based on the relations within the concepts. At a later stage assets were further qualitatively clustered according to the five assets of the livelihood pentagram: human, social, financial, physical and natural assets.

iii. For every asset or aggregation of concepts, relationships between other assets were defined. This definition was based by examining all associated sentences of each concept of an asset, in order to define its impact and influence on other assets.

iv. Linkages between or impacts and influences of every asset were transformed into a binary adjacency matric (Özesmi and Özesmi 2004: 49), whereby 0 is no impact/ influence and 1 is impact/ influence. Other methods using the cognitive mapping approach were applying fuzzy causal functions with real numbers between -1 and 1 (ibid. 2004: 45). Those fuzzy casual functions are representing the relative importance of a relationship between concepts. A negative value accordingly implies a negative impact or influence. Otherwise a positive value implies a positive or reinforcing impact. For the cognitive maps, developed for this study, a weighting of linkages was not applied, because the cognitive maps were representing the structure of an entire community, where a farmer is managing his/ her livelihood. Accordingly all interviews were combined together to define as much relevant assets and their linkages as possible. Consequently relationships between assets might be weighted positive and/ or negative differently by different farmers. This might cancel linkages between assets out (Özesmi 2006: 8). Furthermore, as the cognitive map was developed indirectly based on interviews of farmers and not directly by the farmers themselves, the level of subjectivity was considered to be too high.

v. The cognitive maps coded in binary matric were analysed using the open-source program fcmapper. This program calculates the density of a map, number of concepts (or assets), connections, transmitters, receivers, ordinary (cf. Özesmi 2006; Özesmi and Özesmi 2004), outdegree, indegree and centrality. For this study centrality, outdegree and indegree were used. Outdegree, respective indegree indicate the "degree to which a given concept is affected by and affects other concepts (or assets)" within the cognitive map (Gray et al. 2013: 8). Outdegree (od) accordingly summarizes all outgoing arrows and is calculated using the following equation (cf. Özesmi 2006: 10):

$$od(vi) = \sum_{k-1}^{N} aik$$

Indegree (id) summarizes all ingoing arrows, calculated with the following equation (cf. Özesmi 2006: 10):

$$id(vi) = \sum_{k-1}^{N} aki$$

Centrality (ci) "indicates the relative importance of a concept within then structure" of a cognitive map and represents the sum of indegree and outdegree (cf. Özesmi 2006: 10).

$$ci = od(vi) + id\ (vi)$$

vi. These values were used for the analysis of the baseline scenario. The baseline scenario is "representing the steady state of the system", thus represents the resilience of the socio-ecological system and vulnerability of the individual farmers at the time of conducting the data. The resilience of the system was deduced by identifying the most important concept within the structure, thus the asset with the highest value of centrality. The probability of influence or modification of this asset regarding other assets is thus higher than for others. Consequently all assets that are influenced by this central asset are likewise relevant for the resilience of the system, in a sense that the probability of influence of these assets regarding other assets is higher than for others. For analysing the resilience the five most influencing assets, thus assets with a high value of outdegree, which were influenced by the central asset, were selected. These assets are defining the livelihood activities of farmers and thus are likewise defining the structure of the system.

For analysing the individual vulnerability the five most alterable assets, which influence the central asset were analysed. These assets show a relatively high indegree and hence are assets, which access is manipulable. The access to these assets determines the access to the most important asset for the structure of the system. Individuals which are having a low access to these assets, depending on their livelihood strategies and constraints, accordingly have relatively a lower possibility to access the central asset.

Each cognitive map was separately analysed by using these values. Similarities and differences between the maps were further analysed by comparing their affiliated assets and by standardizing their values, thus calculating for each asset their relative values referred to a hypothetical map where each asset is linked which each other asset. Based on these values the values of the two maps were possible to compare directly, because they were referring to the same hypothetical map.

vii. The small-scale and large-scale scenarios were developed by incorporating the different elements of a biochar system and linking them to the corresponding assets which might constrain an implementation and which are altered by an implementation. The selection of these assets was based on a previous literature review (cf. chapter 2; annex H).

The outcome of the scenarios were analysed according to their alteration of resilience, respective vulnerability. For determining a potential alteration of the resilience of the map, all assets which were influenced by the implementation of a biochar system, were analysed considering their initial outdegree, hence their relative influence on the resilience of the map. To determine the vulnerability of the individual farmers all assets which were necessary for an implementation were analysed considering their initial indegree, hence their potential of ability to have access to these assets.

Scenarios of the different villages were further compared by standardizing their values referring to the same hypothetical map, were all assets were interlinked which each other.

viii. The maps of the baseline scenario further were visualised using the open-source program pajek.

Despite the advantages of the cognitive mapping method of improving the understanding of complex, dynamic relationship within a system, the possibility to deal systematically with a large amount of data without reducing it (Eden 1994: 269) and the possibility to use these maps as communication tool for further planning steps, the method as well has disadvantages. The advantage of the flexibility of complexity of the cognitive maps has on the other hand the disadvantage, that the more complex the map gets, the more difficult it gets to keep the overview. Likewise, the development of a cognitive map based on interview data is an intensive and time-consuming process (Murungwendi et al. 2011: 2). The difficulty while developing the map based on interview data was to stay as close as possible to the information given be the local individuals. Thus while making the map, additional linkages between the assets were obvious, but since none of the individuals mentioned this linkage, a linkage between them could not be made. Another difficulty is that certain relationships might not be possible to translate in an asset to asset relationship, which are the constraints, given by a predefined sensitised conceptual framework.

A cognitive map is always an approximation of a snapshot, in this case of a socio-ecological system, since the information on which the cognitive map is founded is time-dependent and subjective. The dynamics of the socio-ecological systems however change over time (Özesmi and Özesmi 2004: 50). Likewise, an intended sustainable implementation of a biochar system within such a socio-ecological system might not only change "the nature of the solution, but also the nature of the problem" (Eden 1994: 256). This uncertainty might be possible to reduce, if the cognitive map as such and the outcome of a hypothetical implementation could be discussed with the local stakeholders. This might as well help to refine the relationships between the assets and possibly determine their relative importance. The relationships of these cognitive maps were of binary nature, which over-simplifies the reality, hence a consideration of solely assets that have a high centrality, outdegree or indegree value and assigning them a high influence on the socio-ecological system and the individuals within, might only partially mirror the reality. There might be assets within the system, which are having a low centrality, outdegree or indegree value, but might still be crucial for the adhesiveness of the system. The cognitive mapping method is a tool to model, "what-ifs", but "why's" cannot be determined (Özesmi and Özesmi 2004: 59). Results gained by the cognitive mapping method, thus have to be traced back, in order to understand the outcome of the relation pattern between the assets.

5.4.2. Descriptive statistics to analyse the standardized questionnaire

The analysis of the questionnaires were descriptive and not statistically. Weightings of perturbations under different scenario were summarized and their arithmetic means was calculated. Results were visualized graphically. Different strategies and reasons were categorized according to their content, counted regarding to their occurrence and as well graphically visualised. Due to the small number of respondents the results of the standardized questionnaire are not representative, therefore individual data was not used for data correlation or further inferential statistics.

The results of the analysis of this data were used to formulate a "worst-case" scenario. A worst-case scenario simulates different consequences of a biochar system implementation which might have a negative impact on the resilience of the system and vulnerability of the individual farmers. Pre-determined by the sensitising conceptual framework, a negative impact might be reduced by applying different strategies. The more strategies the farmers own, the better they might deal with potential negative consequences.

5.4.3. Qualitative content analysis to reveal benefits, constraints and solutions

For the analysis of the focus groups a data direct qualitative content method was chosen. A qualitative content analysis is a subjective interpretation of the content of a text "through the systematic classification process of coding and identifying themes or patterns" (Hsieh and Shannon 2005: 1278). The coding process is deductive, thus texts were analysed by using a predefined theory framework (ibid. 2005: 1277). Based on existing theory or research data relevant key categories are predefined (ibid. 2005: 1281). This predefined category raster further guides the coding and categorisation process of the text. All the data that does not fall into the predefined category raster, is analysed later to determine if they may represent a new category or a subcategory of an existing category (ibid. 2005: 1282). Contrary to a quantitative content analysis, were text data is as well coded according to "explicit categories" to describe them statistically (ibid. 2005: 1277), results of a qualitative content analysis are described according their "content or contextual meaning of the text [-passages]" (ibid. 2005: 1277).

In this study the analysis of each text resulted from expert and focus group interviews was done based on a predefined category scheme composed of three categories: i) investment reasons, ii) investment constraints, and iii) proposed solutions. The results were further used to complement results derived from the small-scale-, large-scale-, and worst-case scenario.

The purpose of a qualitative content analysis is to "validate or extent conceptually a theoretical framework or theory" (ibid. 2005: 1281), a qualitative content analysis is not bias-free. A definition of a classification raster in advance helps to find within the data aspects that rather support a theory than challenging it. This might undermine relevant contextual aspects of the phenomenon (ibid. 2005: 1283).

6. Results and analysis

The analysis of results was based by an understanding of the dynamics of the socio-ecological systems of Chandagalu and Manoor. Starting-point of analysis was a determination of the crucial elements within the system that are defining the resilience, thus the function of the system and the individual vulnerabilities, thus the structure-building elements of the system (cf. chapter 3.5.). An implementation of a biochar system might alter the function and structure of the socio-ecological systems, hence livelihood activities might directly be affected and are accordingly indirectly affecting the system. This might lead to a modification of the resilience of the systems and the individual vulnerability within the systems. The potential extent of modifications of resilience and/ or individual vulnerability might indirectly indicate social, economic and ecological barriers regarding a sustainable implementation of a biochar system.

The following chapters are divided into an illustration of i) the a baseline scenario of the resilience and individual vulnerability of the socio-ecological systems of Chandagalu and Manoor, and further ii) the potential extent of modification of the resilience and individual vulnerabilities regarding a small-scale, large-scale and worst-case scenario, based on the initial function and structure of the socio-ecological systems. The identification of social, economic and ecological barriers regarding an implementation of a biochar system are denoted in this chapter, but their significance for a sustainable implementation is not part of this chapter. This shall be discussed in the discussion chapter under consideration of additional literature and the results of the focus group discussion. The results of the focus groups, hence as well are not specified in this chapter. They were moreover thought as completion and confirmation of the determined adaption barriers and their significance. To provide an overview, a tabular summary of the results of the focus group is given in the annex J of this thesis.

All illustrations are referenced with statements of the interviewed farmers. A reference of a farmer is indicated with the letter P. Annex D provides an overview about the profiles of the different farmers.

6.1. Baseline scenario

For both villages livelihood assets of the farmers and how these assets are related with each other have been identified. The interrelations of these assets are constructing a network of livelihood activities, which is representing the structure and function of the system. Using the cognitive mapping method, a social cognitive map was developed, mirroring the structure and function of the system. Based on this map, the resilience of the system and the differentiated vulnerabilities of individuals were possible to assess by using the following assumptions:

Within each network or system several key assets are central for the structure and the function of the system. An analysis of these key assets accordingly reveals important factors that define the resilience and individual vulnerability. In the following illustration the focus lies on the most relevant asset within the system, thus the asset that is relatively influencing the most and is relatively affected the most by livelihood activities of the farmers. By analysing the influences of this asset on the socio-ecological system, it is assumed to estimate the function or resilience of the system, thus, the dynamic interplay of livelihood assets, activities and strategies of farmers to secure their livelihood - in which the depicted key asset is playing a significant role - facing internal and external perturbation.

Contrarily by analysing the access of the assets, that are influencing the key asset of the system, the structure and how different individual vulnerabilities preserve this structure might be assessable. The vulnerability of a farmer depends on the amount of assets he/ she is having access to. If an individual is constraint by his/ her access to assets and if these non-accessible assets are hindering him/ her to have access to the key asset of the system, consequently his/ her vulnerability increases. Otherwise the more assets that are accessible, the more reactive strategies against perturbations are possible and the less vulnerable is the farmer and the better he/ she is able to have access to the key asset of the system.

The following chapters illustrate, how an assessment of resilience and vulnerability might be possible, based on the baseline scenarios of Chandagalu and Manoor, which were modelled with the cognitive mapping method.

6.1.1. Baseline scenario of Chandagalu

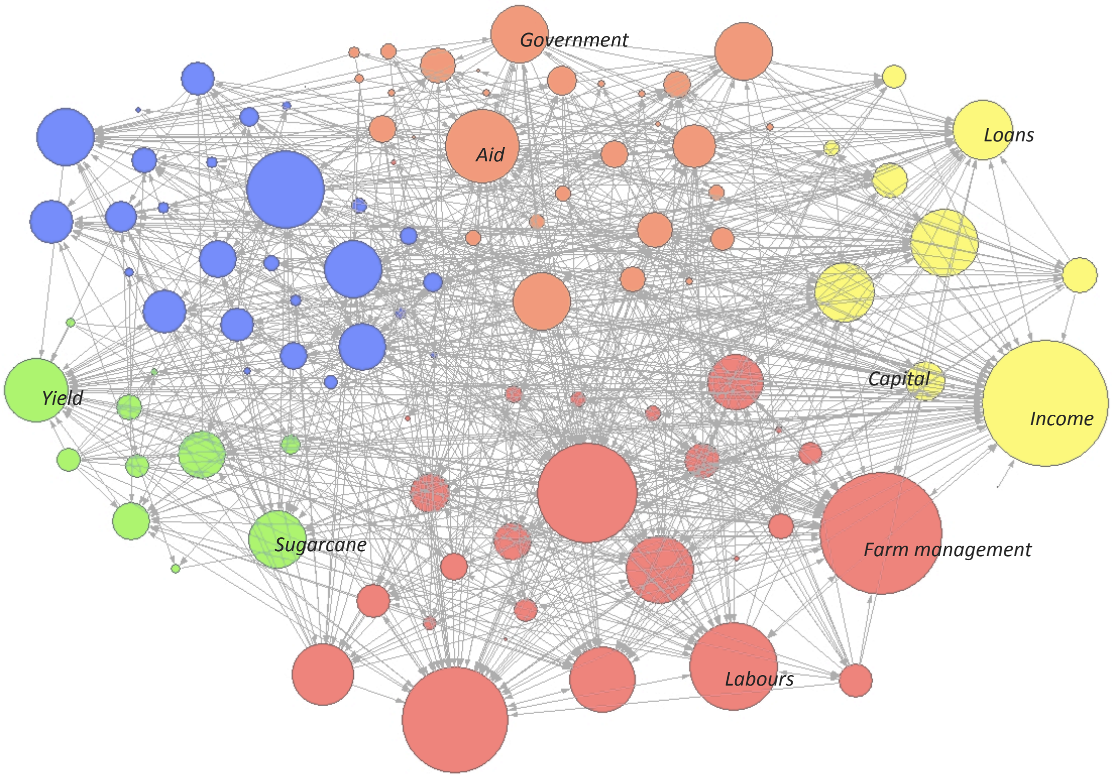

Figure 9: Social cognitive map of Chandagalu, which is representing the baseline function and structure of the farming based community.

The baseline scenario that is represented by above illustrated cognitive map of Chandagalu, is constructed by 107 concepts, which are representing the livelihood assets of farmers (cf. figure 9). In total 26 human assets, 32 social assets, 9 financial assets, 28 physical assets and 12 natural assets were identified. Each of these assets has its specific function within the structure of the system. This function is represented by its connections within the system. Every connection represents either a negative and/ or positive direct or indirect impact or influence. All livelihood assets together were connected by 813 connections. Concepts or assets, which have in total a high number of in- and out-arrows are central concepts of the map, and are crucial for the structure, respective for the function of the map (cf. table 4).

Table 4: Results of social cognitive map of Chandagalu.

Characteristics of social cognitive map of Chandagalu	
Nr. of variables	107
Nr. of connections	812
Nr. of human assets	26
Nr. of social assets	32
Nr. of financial assets	9
Nr. of physical assets	28
Nr. of natural assets	12
Most central concept/ asset	
Income	71

The most relevant asset that is central for the inherent structure and function of the system is *income* (cf. table 4). Accordingly this concept or asset is holding the structure together and is relevant to consider for an understanding of the function of this socio-ecological system. Income has an impact on 17 assets and is influenced by 54 assets. Income influences 9 human assets: *satisfaction, mobility, independency, farm management, self-initiative, being innovative, confidence, labours, employment;* 1 social asset: *milk society*; 3 financial assets: *capital, self-sufficiency, loans;* 1 physical assets: *jaggery house;* 3 natural assets: *sugarcane, paddy, diversity of crop.*

On the other side income is influenced by other assets: 10 human assets are influencing the income of a farmer: *family support, information/ knowledge, mobility, health, age, employment, education, farm management, self-initiative* and *labours*; 13 social assets: *social value, social status, unity/ cooperation, aid, job possibilities in the city, VC farm, hoblis*[3]*, government, milk society, apmc shops*[4]*, middle-men, political decisions, market;* 4 financial assets: *refund, subsidies, loans, guaranty*, *market price*; 17 physical assets: *irrigation system, storage, livestock, drumseeder*[5]*, jaggery house*[6]*, silkworms, biogas plants, rice mills, sugar factory, machine for harvesting, transportation, fertilizer, seeds, medicines*[7]*, yield protection, manure;* and 10 natural assets: *length of growing season, soil quality, climate, rainfall, yield, sugarcane, paddy, groundwater, wood, diversity of crop* are influencing the income of a farmers.

6.1.1.1. Resilience of the socio-ecological system of Chandagalu

An analysis of the most influencing assets that are influenced by the income reveals the most relevant drivers of livelihood activities of the farmers and accordingly of the resilience of the system. The 5 most resilience-shaping assets, which are influenced by the income, are *farm management, labours, capital, sugarcane and paddy* (cf. table 5)

Farm management is influenced by the income, by determining its choice of decisions. A farmer has to make his living by the production of cash and food crops. Accordingly he/ she chooses to produce the crop, that will likely sustain his/ her livelihood.

[3] Hoblis is a subdivision of Mandya taluk, a place where subsidised seeds are available.
[4] APMC shops are places were farmers are selling their paddy for a fixed governmental price.
[5] A drumseeder is a machine, which is placing seeds mechanically without the need of labours.
[6] A jaggery house is place where a farmer can sell his sugarcane.
[7] Medicines against plant diseases, such as pest, insect attack, etc.

"Because I have to eat and I don't know what else to do. I already have received a loan and I need to pay that back. […] For one acre I produce 30 quintals and paddy is 1400 IRS per quintal. Sugarcane is not that profitable. At least for paddy I keep some for my family" (P2).

"I also know vegetables. But it is not the right time now, because there is no sure price. You can produce huge tonnes of tomatoes, but if one box of tomatoes once costs 200 INR and then 100 INR, it will be a huge loss" (P19).

Table 5: The 5 most influencing assets that are influenced by income (Outdegree > 13).

Human assets	
Farm management	22
Labours	22
Financial asset	
Capital	18
Physical asset	
Sugarcane	14
Paddy	13

The choice of producing a specific crop, caused by the need of generating income, to sustain his/ her livelihood has a range of consequences to the entire system. Directly affected are human assets, such as availability of *time* (e. g. P13) or the level of *satisfaction* (e. g. P5; P6), etc.; financial assets, such as *income* (e. g. P6; P9), *capital* (or savings) (e. g. P14, P19); physical assets, such as need of *irrigation system* (e. g. P1; P5), use of machines, such as a *drumseeder* (e. g. P16), or use of agricultural products, such as *ash* (e. g. P2; P11), *fertilizer* (e. g. P7) or *manure* (e. g. P4; P15), or natural assets such as *diversity of crops* (P6), etc.

Likewise ***labours*** is an asset that is influenced by the income, because labour costs are generally high (P7; P8). For this reason farmers reduce the amount of labours for farming as much as possible and replace them if possible by machines.

"I am happy about this time, that I have no trouble a lot with farming, because I got the yield, and have done it with very few labours" (P9)

"You need a machine which can replace the labours. Because this is the problem we are having." (P13).

On the other side many farmers are depending on additional labouring work. A replacement of labours by machines consequently risks their jobs (e. g. P4; P12).

Capital (or savings) is another asset that is influenced by the income and has a high impact on the resilience of the structure, thus capital empowers farmers to make use of and thus influences divers assets within the system. Assets, which are influenced by the capital, are moreover human and social assets, such as *power* (P3), *responsibility* (P20), *satisfaction* (P9; P14), *farm management* (P14), etc. and a few physical assets, such as *irrigation system* (e. g. P13), *technology* (P13) or *biogas plant* (P7).

"People who are still growing are people who have put wells, so that you get water. […] we would also like to do this. But then you need money for it" (P13).

> *"Yes, there are people who are having money issues and are not doing so well. But there are also people who have no money issues, they are doing fine"* (P9).

> *"There is an income but we are not able to save it. What would help us would be money"* (P14).

Sugarcane and ***paddy*** are the main crops that farmers in Chandagalu are growing to generate their income. However sugarcane and paddy are both influencing the system by determining certain activities. Sugarcane generally is *"an easy plant to handle"* (P13), because less workers are needed than for paddy. Likewise the growing period of sugarcane is shorter than for paddy, which results in additional free time to work elsewhere.

> "*You need to put good manure. And fertilizer. And time is important. Putting manure and fertilizers at the right time, than you will have a good yield. (...) It works out better for us to grow sugarcane, because it is one time we have to work and we will be free for the whole year. But if you grow paddy, this is not the case"* (P12).

> *"If I need to work and if I put sugarcane and I work for three months and the rest of time I am free and do some other labouring job, this is what I want to do"* (P12).

Paddy on the other side is an important food crop for farmers in Chandagalu (P2). But producing paddy requires more *time* (P19), more *labours* (P1) and a certain *capability to work hard* (P17).

The function of the socio-ecological system accordingly is based on gaining income to survive. This is tied to certain consequences, based on how certain livelihood activities that are influenced by the generation of income are themselves influencing the system. The level of resilience of the system consequently is in continuous movement. However, as long as the system is fulfilling its function, the system can be considered as resilient.

6.1.1.2. Individual vulnerability within the socio-ecological system of Chandagalu

The individual vulnerability of the farmers is structure-building. The structure in this sense is a consequence of the sum of all different livelihood activities that are tied to the generation of income. Thus not every farmer is having access to certain assets that are crucial to generate income. For this reason, they might have to develop livelihood strategies, in a sense that they make use of other accessible assets. Accordingly, the sum of farmers' activities and strategies, based on their access to assets represents the structure of the system. An alteration of the access to certain assets might change the individual vulnerability of the farmers, if they cannot substitute the lack of access by the use of another asset. Depending on the flow and intensity of change of alteration of certain vulnerabilities, the structure of the system might change.

The 5 most manipulable assets that are influencing *income* are *farm management, labours, aid, loans and yield* (cf. table 6). Accordingly the probability of a perturbation of these assets might be higher than for others and hence might increase the vulnerability of farmers, if they do not own adaptive strategies to secure the access to these assets. The following outlines illustrate the various ways, how the access to these assets is shaped and how farmers developed the ability to ensure their access to these assets. Certain access to these assets is partial-determined by the livelihood strategies of an individual farmer; other access to assets is determined by external influences.

Table 6: The 5 most alterable access to assets that are influencing the asset income (Indegree > 20).

Human assets	
Farm management	42
Labours	23
Social assets	
Aid	23
Financial assets	
Loans	26
Natural assets	
Yield	25

Farm management and *income* are strongly linked, as the main income activity of the farmers is based on agriculture. Access to *farm management* is partial-determined. *Farm management* refers to the decision of a farmer how he/ she is managing his/ her farm. An optimal *farm management* decision leads in the best case to a good yield and accordingly to a good income, but as well is generating costs, that influence the income negatively.

> *"I put in interests and do the right thing, put medicine and growing properly, than I get a good yield, otherwise not and I am not getting a good price"* (P6).

> *Yes, I am having a lot of expenses. […] For one acre I am having an expense of 20 000 and 3 times that is the profit that I am making* (P9).

Farm management decisions that increase the yield range from monitoring activities *"constantly watching"* (e. g. P1; P2; P6; P9; P12-P15) to intentional farm activities that are intent to increase the yield, such as *"give water at the right time"* (e. g. P13; P14; P19), *"plant at the right time"* (e. g. P14; P16), *"harvest at the right time"* (e. g. P15), *"in between crop planting"* (P3), *"crop rotation"* (P7), *"fire the land"* (P4), *"clear the weeds"* (P4; P13); and activities tied by the acquirement of agricultural products *"put medicine"* (P2; P4; P6; P7), *"put salt"* (P4; P5; P13), *"spray chemicals"* (P2), *"put fertilizer"* (P12; P13; P20), *"put manure"* (P8-P14), *"get the seeds at the right time"* (P14; P12) and *"controlled use of fertilizer"* (P11).

Access to these optimal farm management decisions is partially manageable by the individual farmers, but is equally determined by assets, whose access cannot be controlled by every individual farmer. Access to an "irrigation system" to "give water at the right time" is not available for every farmer.

> *"Canal work is going on, so there is no water. Next year they will be finished"* (P14).

> *"What can I do, I can only do farming. The water is not here, whatever there is available; they are giving it to the neighbouring state. I cannot do anything*" (P17).

> *"What change can you get? You have to buy 60 000 to 70 000 INR for a well, but there is no guarantee, that there will be water. Only depths again will be left. The only thing you could do, is depending on natural rain or god"* (P18).

Likewise the farm management decision to *"plant at the right time"*, *"harvest at the right time"* or *"clear the weeds"* is not fully controllable by the farmers. In all these activities labour force is involved. However farmers claimed that there are not enough labours available, which makes it difficult for them to freely choose their farm management decisions.

> *"I didn't have had enough labours to manage at that time when I wanted. It's been a continuous problem with these people. The labours where not available, when we needed them and we could not pay them. Because they used to come and work for one day and then they just vanish the next day"* (P2).

> *"The problem with the workers is, the same time when you need the women-workers everybody else also needs them"* (P8).

Activities that are tied to the acquirement of agricultural products are dependent on the access to these products. This access is dominantly determined by market prices, which farmers are not able to control.

> *"That is what the government is giving. They are increasing the price of manure and they are not increasing the price for sugarcane"* (P17).

> *"If I could change something and if I would be in the position to change, I would have changed the costs for the manure, whereas it is available to the farmers freely or for a lesser price. And I would have made sure that the seeds are available at a lesser price"(*P6).

> *"And the fertilizer costs are also high. There are no subsidies from the government. Which has had been removed"* (14).

Labours are not only influencing the access to a free choice of farm management activities and hence the outcome of yield; labours are as well influencing the income of a farmer directly, because hiring them involves costs.

> *"For a farmer the cost of a labour is high"* (P7).

> *"Yes, I am having a lot of expenses. Most of the problems are labour problems"* (P9).

There are three possibilities to reduce labour costs i) using machines instead of labours, ii) only get labours when required, or iii) do the work yourself.

> *"There is a drumseeder for paddy - this is a process of soaking the seeds overnight for 24 hours and draining out the water. There is no oxygen to take out the water. Again for 24 hours. This is before sprouting; you take that and put it into the drums trough, which the planting is happening. By then you also have to prepare the land equally, so that you can start putting the seeds. Now, the labour problem is reduced. For one acre you need 14 women to do this work, now it's only two people. One person to take it further and one person in the back"* (P7).

> *"Nobody has labours all the time in the house. We have 2 - 3 when they are required"* (P15).

> "*If I do the work by myself and I am not using too much labours, than I can make a profit"* (P11).

But not all the farmers are having access to assets, which are necessary to use these strategies. If in any case access to these assets, such as *technology*, *capability to work hard*, *time*, *capital,* etc. is not given farmers might decide to stop farming.

> "*Labour problem is one of the issues why some of them have stopped farming, because it has become very expensive"* (P14).

Aid influences the income directly or indirectly. Direct financial help is provided in form of informal money lends (P12). Indirect financial help ranges from *"working on each other's land"* (P7), *"exchange of food"* (P8), *"giving advice for farm management"* (P1) or *"lending machines"* (P18). Help is provided by family members, friends (P15), neighbours (P7) or VC farm employees (P1).

> "*When we grow something and anybody is in need we give. And when we need something from the neighbours they help too. We also help each other financially. We give and take. We also help each other in the land"* (P8).

> *"We work in each other's land or we lend our ox. In a village we have to help each other"* (P18).

> *"So, also the VC-Farm people here are helping us, by getting a better yield"* (P1).

Access to direct or indirect financial help is provided within the community, however governmental help, as farmers are claiming, is not sufficient available.

> *"The government is not paying anything. The government has not given anything to us, last year there was a drought and they didn't give us anything"* (P16).

Loans are essential for the income of the farmer. In cases of a bad year, where not enough income was generated, farmers have to get loans in order to have enough to sustain their livelihoods (P1; P18). Loans are provided by the *government*, *VC farm* (e. g. P12), *bank* (e. g. P14; P12) or *Swasaya Sangha* (e. g. P14; P18; P19), which is a self-help group for female farmers.

> *"I am a member of a club (Swasaya Sangha), where people pull in money every month. This club is also giving loans. There are about 20 people as a group. The group is formed individually by people, who trust each other. One day a month we meet and everyone can have a loan once in a year. My turn is in June"* (P19).

However to get a loan is tied to certain conditions, that have to be fulfilled. If these are not fulfilled a farmer has to labour him-/ herself.

> *"At this bank we are getting interest free loans, but it is imitated according the size of land. If you need more than that you have to get a loan somewhere else. So far we didn't need it, but now we do. This is the reason why we went to the VC farm and took a loan for a higher price"* (P12).

> *"No, I don't get any help. I have to do labouring work. Nobody will give me a loan"* (P4).

The ***yield*** undoubtedly directly influences the income of a farmer (P18). However a good yield depends on different assets, such as *farm management* (e. g. P6) *soil quality* (e. g. P1) *and irrigation system,* respectively *rainfall* (P4). Certain farmers are having access to these assets, others do not.

> *"It wasn't raining for six months. [...] I am going through a bad time right now. The roots have been died. Even if I water more, the roots are not growing. This year will not be a good one. The sugarcane plants are not developed. I cannot give them to the sugar factory, because instead of a full growing season of 12-13 months, my plants have not completed a full term, they are having a growing stay of 10 months. I can try to give it to the jaggery house, but there I will get 10 000, instead of 25 000"* (P4).

"My land consist of three types, so I am having a good, coloured soil and another one where the yield is ok, but the other one is a clay soil. If I am having water it is fine, but otherwise it brakes. And I am having a soil where the yield is never good. This is a rocky soil" (P1).

Based on these outlines it is possible to assess farmers that are particular vulnerable regarding the generation of income. These individuals have a restricted access to liberal farm management decisions, thus they strongly depend on natural or canal irrigation systems, the availability of labours or the market prices. Certain farmers might mitigate these constraints by building wells or by using machines instead of labours. But low groundwater levels at certain places make it impossible to use a well or sufficient capital is not available, thus agricultural machines cannot be used to substitute labours. For certain famers' aid therefore is crucial for their surviving. Aid is available within the community, but for certain situations may not be sufficient. Accordingly farmers claim to receive more governmental aid that is perceived as not being sufficiently available. In such delicate situations, a farmer might have to take a loan. But as well there are certain farmers, who cannot fulfil the criteria to get a loan, whether they have not enough land or no legal land rights, or are appraised to be not able to pay the loan back. Thus the only solution for them is to labour themselves and carry double the burden. If in such a situation no yield occurs, a farmer has likely reached a very high level of vulnerability.

6.1.2. Baseline scenario of Manoor

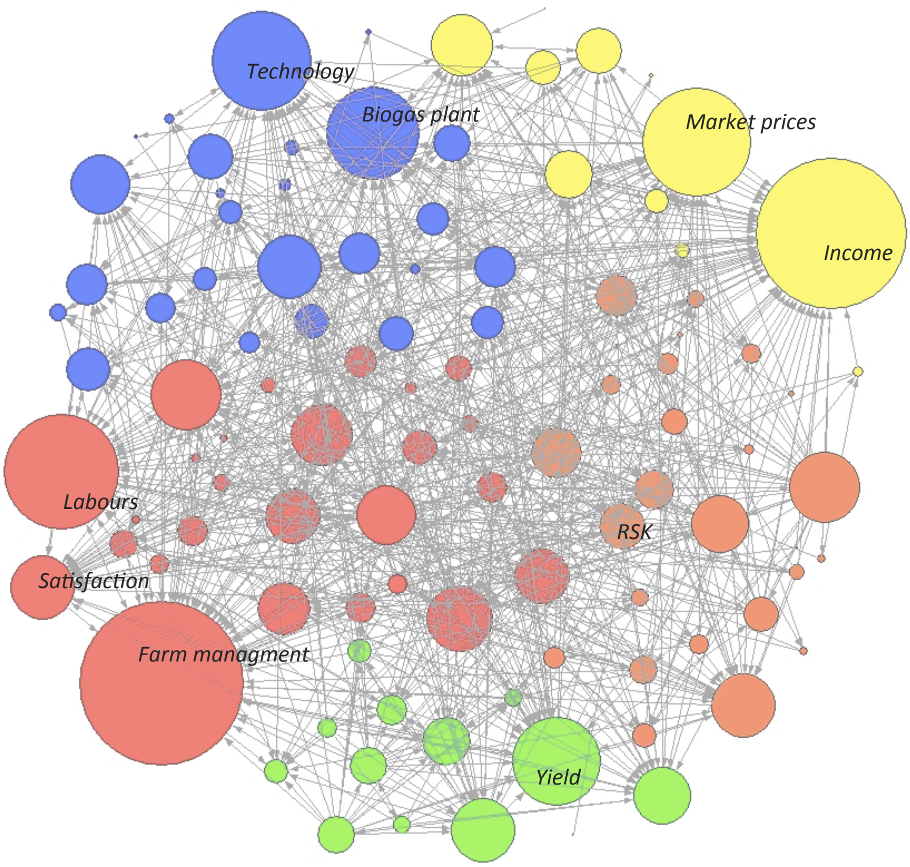

Figure 10: Social cognitive map of Manoor, which is representing the baseline function and structure of the farming based community.

The cognitive map of Manoor is constructed by 105 assets, whereat 28 are human assets, 28 social assets, 10 financial assets, 27 physical assets and 12 natural assets. 862 connections are building the resilience of the map (cf. figure 10; table 7).

Table 7: Results of social cognitive map of Manoor.

Characteristics of social cognitive map of Manoor	
Nr. of assets	105
Nr. of connections	862
Nr. of human assets	28
Nr. of social assets	28
Nr. of financial assets	10
Nr. of physical assets	27
Nr. of natural assets	12
Most central concept/ asset	
Farm management	82

The most relevant asset for the inherent structure and function of the system is *farm management.* Accordingly this concepts or assets holds the structure together and thus should be considered for the understanding of the individual vulnerabilities within this socio-ecological system, but as well is responsible for the function of the system that can be assessed by analysing the influence of this central asset for the socio-ecological system.

On the one side farm management has an impact on 27 assets and is influenced by 55 assets. Farm management influences 5 human assets: *labours, capability to work hard, time, give help to other, reputation;* 3 social assets: *RSK, unity/ cooperation, Krishi Mela*; 3 financial assets: *market price, income, profit* 9 physical assets: *technology, ash, livestock, rice hull/ husk, fertilizer, manure, machine for harvesting, charcoal, machine for planting, sugar factory.*

Farm management on the other side is influenced by 12 human assets: *labours, satisfaction, confidence, capability to work hard, information/ knowledge, trust, give help to others, time, self-initiative, being innovative, gender, mobility;* 13 social assets: *Aid, family support, unity/ cooperation, equity, community, RSK, political decisions, scientists, insurance, job possibility in the city, panchayat, believes, media*; 3 financial assets: *Market prices, capital, subsidies;* 20 physical assets: *biogas plant, technology, paddy, ash, manure, fertilizer, seeds, livestock, rice hull/ husk, irrigation system, transportation, salt, storage, minerals, silicone, machine for planting, charcoal, land size, machine to prepare the land, uria and potash;* and 7 natural assets: *yield, diversity of crops, soil quality, seasonality, rainfall, climate, sea* are influencing the management decisions of a farmer in Manoor.

6.1.2.1. Resilience of the socio-ecological system of Manoor

The influence on the system of certain assets, which is influenced by farm management decisions, is higher than for other. The 5 most influencing assets are *labours, RSK, market prices, income* and *technology* (cf. table 8).

Table 8: The 3 most influencing assets that are influenced by farm management (Outdegree > 16).

Human assets	
Labours	20
Social asset	
RSK	16
Financial asset	
Market prices	21
Income	17
Physical asset	
Technology	16

Labours are influenced by farm management decisions, because there are needed for farming.

> *"The thing is you need these labours to do the seeding/ transplanting […]"* (P22).

> *"If you get the labours at the right time, we will have a good yield. But if you don't get the labours at the right time, it is like 15 days to late, than you will not have a good yield"* (P27).

In turn farmers are not able to pay them the wages they are asking for. For this reason labours decide to do other jobs and farmers otherwise try if possible to replace them by machines.

> *"Moving to the city and do jobs like painting houses. Because there is hot sun, you need skilled labours. Or a machine, which could be used in everybody's field* (P28).

> *"The labour problem. Earlier we had 25 labours, which came and helped, but right now, there are only 5 of them. That is because everything is getting replaced by machines"* (P24).

RSK is influenced by farm management decisions, in cases when farmers ask them for advice. In turn RSK provides *information/ knowledge* (e. g. P23; P25) about new *technologies* (e.g. P21), good quality *seeds* (e. g. P22; P23), soil nutrients (e. g. *salt, diapen*) (e. g. P26), *loans* (P29), or soil tests (P21).

Market prices are influenced by farm management decisions, because of the farmers decision to stop storing their paddy. This influences the market prices, because if the market gets flooded by rice, the market prices for rice decrease. As a consequence the income of farmers are tangent and their dissatisfaction with the system increases.

> *"Initially the farmers used to store the rice/ grain. Now they don't because nobody wants to do the hard work and because of that there is more rice on the market. Since there is more, because everybody is growing it, they value of it is reduced"* (P22).

> *"The price what we are getting for the production is not right. […] Only our product or what we sell is not. […] What we get last year 1800 INR, now we are getting 1200, 1300 INR this year. Though the yield is good, we are not getting the right prices on the market"* (P25).

> *"Every skill should be appreciated as what it is. Why is that, that one skill is so much, and the other skill is not appreciated? […] In the US every kind of skill is appreciated, even the farmers are appreciated for their hard work. They are getting a good price and they all are living equally"* (P25).

Farm management decisions influence the ***income*** through expenses needed for farm management and also through its outcome, either a "good" or a "bad" yield. Income on the other side influences what farmers are able and willing to do and what not.

"If I get a good yield that would be the best thing for me. Because when you get […] more money and everything would work out" (P25).

"Too much of expenditures (for a biogas plant) and too much of work" (P21).

"Everybody has their own capacity to live and earn. If you see some people, they are having 10 acres of land and they are having tractors and they are doing well. And there are people who have less land, like 1 acre, ½ acre and they are also living, but the thing is for them, whatever they are earning form their land is not enough, the expenses are high compared to the income from the land" (P22).

Technology is another asset, which is influenced by farm management decisions. Technology or agricultural machines are used for planting (P27) or harvesting (P32). Likewise an agricultural machine might be an additional income source (P22) or as a possibility to replace labours and thus save the labour wages (P28).

"If you want to go into the agriculture field, you need more land and more machines. You need mor land and to work on the land you need machines" (P21).

"I have a machine which tills the land and I give this tiller to the people to utilise it. This is like a rents, they pay me and then they get it. I receive money from that" (P22).

"To plant now we use these lady workers. If something would come with respect to that, that would help" (P27).

The function of the system is mainly based on farm management decisions. The maintenance of this resilience has certain influences on the system. For Manoor as illustrated above, labours, RSK, market prices, income or technology are directing the movement of the resilience of the system.

6.1.2.2. Individual vulnerability within the socio-ecological system of Manoor

The five assets, which were influencing farm management and hence contribute essential to the resilience of the system are *satisfaction, labours, biogas plants, technologies* and *yield*. However not every farmers is having access to these assets. Their vulnerability thus is expressed by their capacity to have access to these assets, in order to be able to make more or less unconstrained farm management decisions (cf. table 9).

Table 9: The 5 most alterable access to assets that are influencing the farm management (Indegree > 27).

Human assets	
Satisfaction	29
Labours	31
Physical asset	
Biogas plants	35
Technologies	31
Natural assets	
Yield	28

Satisfaction is influencing the farm management in a sense, that satisfied farmers invest more effort and capital into farming. Satisfaction is partly influenced by individual's internal factors, such as personal *attitude* (P21; P34) or *believes* (P24). Otherwise it is influenced by external factors, such as *self-sufficiency* (P34); *profit* (e.g. P21; P25), *yield* (P23), *labours* (P22) or *social value* (P25) etc.

> *"[…] I am not interested to invest in agriculture […] because I don't think, that there is a bright future. If my son is going somewhere else, I will definitely drop this"* (P29).
>
> *"I am happy, because I've got a lot of recognition and got awards. I am also somebody who is looked after the state award. Satisfaction is there"* (P23).
>
> *"There is nothing that I don't like, it is a part of my life. The service to do for the cows is as good as to do service to the gods"* (P24).
>
> *"What I grow I can eat. Because I work in the field and because of the air, the health is good. I am happy that a lot of people are there to work"* (P34).
>
> *"The government gives marges or subsidies for every kind of industries, but what are they giving to the farmers? If they make it more attractive to the people to get into farming, only then it is possible, than there is a change"* (P25).

Labours are needed for several farm activities, such as *"cleaning the field"* (P24), *"putting the ash on the field"* (P24), *"planting"* (P25), *"plucking the land"* (P21), etc. But labour availability is influenced by external factors, which are not alterable by the farmers. Reasons that were mentioned were "*education"* (P24), "increase of labour wages" (P25), *"governmental scheme"* (P25) or *"industrial change"* (P25).

> *"The kids are educated and tell them not to come work here"* (P24).
>
> *"Every farming land had one labouring unit. The labours used to come to work, because they have had no other choice. They dependent on this work, where they could get money. And now, that is not the case, because fishing industry has improved and every other labour has need and living for himself in every different way which is ok. They have no need any more to come here and work. So they are not dependent on us. And also we are not able to give them the kind of wages, which are required. That is why they don't want to come and work. Initially the labours when we wanted to pay them they have not been happy, they asked for rice. Now, there is no value for rice"* (P25).
>
> *"It is been the custom here and if I want to pay more here it is not possible, because than I have to answer to the neighbours, why I am paying more"* (P36).

In Manoor ***biogas plants*** were used not only for cooking, farmers of Manoor are using the remaining slurry also as manure for the field (P32). They mix it with rice hull husk ash (P32) and distribute it on the field.

> *"We are using the ash with the slurry of the biogas and the grass. We are creating a compost and then we are using it"* (P21).

However is not possible for every farmer to use a biogas plant. There are several assets, which are needed, in order to have access to the benefits of a biogas plant. These are *"loan"* and *"subsidies"* (P23), *"ash"* (P21), *"land rights"* (P31), *"labours"* (P25), *"believes"* (P23), *"capability to work hard"* (P31), *"time"* (P25), *"information/ knowledge"*, (P21) or *"livestock"* (P27).

"I took a bank loan. One third have been subsidies" (P23).

"You need a worker to put the cow dung and turn it. Initially we have been a big family of 14-15 members, and somebody used to do it. It becomes very difficult, especially during the harvest time, plantation time" (P25).

"I was one of the first one who did it, because we didn't get the other gas [...] There was no supply in this area and there was a believe, that the food cooked by gas is not healthy" (P25).

Technology does not only have an influence on farm management decision, but also technology or specifically agricultures machines are only used for farming, if farmers perceive them as useful and enough capital is available to access them (P27). Certain machines were not used, because they were perceived to negatively influence other relevant assets needed for farming, such as "livestock" (P29; P33), "soil or crop quality" (P22; P36) or "income" (P35). Likewise the land in Manoor is very fragmented and roads are in bad conditions (e. g. P21), thus it is difficult for the farmers to efficiently reach their land with the particular machines (P29).

"But the thing is, some difficulties are also there. We want grass. In manually it is more, in machinery it is less, because it gets spoiled. Nothing to worry about that is being our land only. But for the cows, it is very difficult" (P29).

"[...] when you are blowing the land, using the machine, sometimes the soil becomes very tight. There is no air. So, during those times, you don't get a good yield" (P36).

"The machine we have now (drumseeder) [...] our land if we do it for 2 inches, the plant is not properly put in and it gets spoiled. So, we need it that 8 inches one" (P22).

"There is nothing like a good year [...] the prices for the machines for blowing and for cutting are also high" (P35).

"Here the major problem is, the lands are not well distributed. For that only we have to maintain buffalos, otherwise the machine will do that" (P29).

The aim of a good ***yield*** is consequently influencing farm management decisions. A good yield depends on many factors, such as *"putting ash"* (P27)*, putting cow dung"* (P28)*, "putting manure"* (P22)*, "putting minerals"* (P27)*, "intercropping"* (P26)*, "japan farming"* or *"straight line farming"* (P21; P28)*, "use of fertilizer"*(P34)*, "removing the salt content from the soil water"* (P21)*, "diseases"* (P21), etc. But not every farmer has access to these farm management activities.

"The problem is we put ash into the soil at the time of groundnuts, we didn't put it for paddy. And we don't get enough. Also you need labours" (P27).

"I put manure, for which I use the cow dung and if I think it is less I buy minerals from the government. But what they give is not much, it is very less" (P27).

"The work for the labours is more, when you do it the straight line. Sometimes workers refuse to put it in a straight line. It is scientifically proven, that the straight line is better, but the labours refuse to do it" (P21).

Farmer's individual vulnerability regarding farm management is shaped by the access to satisfaction, labours, biogas plants, technologies and yield. As illustrated not every farmer has access to these assets. Farmers are especially vulnerable if they perceive their life as farmer as non-valuable, or if access to labours or new technologies is not provided and if the farmer cannot sufficiently improve the yield.

6.1.3. Similarities

The analysis of resilience and vulnerability of the two different systems have implicit shown the differences in structure and function of the systems. However in certain aspects the systems are similar.

Table 10: Central concepts with similar high centrality value (> 15%).

Human assets	
Aid	16 vs. 16
Satisfaction	17 vs. 15
Financial asset	
Market prices	17 vs. 21
Income	33 vs. 33
Physical asset	
Labours	21 vs. 25
Natural asset	
Yield	18 vs. 21

Chandagalu and Manoor have similar high centrality values for the assets *aid, satisfaction, market prices, income, labours and yield.* These assets accordingly are shaping the socio-ecological system equally strong, in a sense, that these assets have a relatively high influence on the function, respective resilience of the socio-ecological system, and on the structure or individual vulnerability within the system (cf. table 10).

Table 11: Central concepts with similar low centrality value (< 3%).

Human assets	
Age	2 vs. 2
Openness	1 vs. 1.5
Social asset	
Bank	0.5 vs. 0.5
Physical asset	
Garbage collection point	1.5 vs. 1
Charcoal	2.5 vs. 3

Assets, such as *age, openness, bank, garbage collection point* and *charcoal* have a low impact on the resilience of the system. This is caused by the reason that these assets have a relatively low influence on the system, either because they do not exist yet, such as a ***garbage collection point***, or because their usage has a relatively low impact on the system, such as ***openness***, ***charcoal*** or ***bank***. The individual vulnerability otherwise might be strongly affected by these assets, because they provide a relatively low accessibility. Access to ***age*** thus is not alterable but can have a significant effect on the livelihood of a farmer. Likewise access to a ***bank*** as such is not alterable, but by providing loans banks are significant important for the livelihood if a farmer (cf. table 11).

6.1.4. Differences

The prominent difference of Chandagalu and Manoor are their different key assets, which are structuring and shaping the function of the system. An analysis of all different assets and activities that are structuring and shaping the function may explain this difference.

Table 12: Concepts of social cognitive map that are only occurring in Chandagalu.

Chandagalu		
Human assets		
Give work to others (1%)		
Social assets		
Hoblis (1.5 %)	Provision store in Mandya (1%)	VC farm (12%)
Holalu (1%)	Rumours (5%)	Multi-national companies (2.5%)
Mandya Agro (1.5%)	Social acceptance (2%)	
Swasaya Sangha (2%)		NGO (2%)
Financial assets		
Guaranty (9.5%)		
Physical assets		
Health care possibilities (2.5%)	Sanitary possibilities (2.5%)	Yield protection (2.5%)
Jaggery house (9.5%)	Silkworms (2.5%)	Medicines (3.5%)
Chicken farm (0.5%)	Drumseeder (5.5%)	Earthworms (2%)
Natural assets		
Length of growing season (2.5%)	Ragi (2%)	Sugarcane (14.5%)

Important assets for the social-ecological system (> 5%) of Chandagalu, which are not occurring in Manoor are *VC farm, guaranty, jaggery house, sugarcane, drumseeder* and *rumours* (cf. table 12). ***VC farm*** is an agricultural college close to Chandagalu. This VC farm provides *"information to optimize farm management"* (e. g. P12; P19), *"subsidised seeds"* (e. g. P1; P4; P11), *"agricultural machines"* (P18), *"fertilizers"* (P18), *"medicines"* (P18), etc., thus is important for a farmers livelihood. On the other side the access to these supplies is constraint by human assets, such as "*believes"* (P13; P19) or "*trust"* (P15), which are influencing a farmers decision whether he/ she takes the help of VC farm or not.

The asset ***guaranty*** refers to farmers' risk-averse tendency to utilise only *"seeds"* from places, where there is a guaranty to receive a refund, if no yield occurs (P7). But there are differences between these guaranties: Private *multi-national companies* (P10) are only giving a refund, in cases the seeds were not germinating, governmental seed providers, such as *VC farm, Panchayat, Krishi Mela* are giving as well a refund at a later stage of production (P10). In certain cases farmers cannot take seeds with guaranty, because they are too expensive or because they were not produced, caused by water scarcity. In such cases they borrow them from the *neighbours*, which have an *irrigation system* (P9) or use seeds from previous seasons (P12). Guaranty is likewise important for the choice of farmers, where they sell their *yield*. If they are selling their yield to the *sugar factory*, they are certain, that they take the whole yield. This is not the case with the *jaggery houses*, where they take only high quality crop (P13). For certain assets farmers have no access to guaranty, such as *market prices* (P19) and *groundwater* (P18).

Jaggery houses are places were farmers can sell their yield. Hence they are relevant for the structure of the system. Jaggery houses generally *"give [...] a lot more money than the factory"* (P1). But as mentioned, under the condition, that the crop has a high quality (P13). Jaggery houses likewise provide *ash* that is used by the farmers as *manure* for their field. But the amount provided by the jaggery houses is not enough for all farmers (P11). Owning a jaggery house generally is supposed to be profitable, however, since market prices of jaggery decreased and labour costs increased it is difficult for jaggery house owners to make profit (P5; P11; P17). Important assets for surviving as jaggery house owner are *"unity/ cooperation between family members"* (P11) or *"being active"* (P5), in sense to actively inform him-, or herself about market conditions and *"constantly watching the yield"*, in order to *"cut the yield at the right time"* (P5).

Sugarcane is not mentioned in Manoor, thus it is not their main crop of production. Otherwise in Chandagalu, were *sugarcane*, *paddy,* and *ragi* are the main crop that are cultivated. *Sugarcane* is an important cash crop for the farmers in Chandagalu and therefore crucial for the income of the farmer. Successful cultivation of sugarcane and thus income generation, however, strongly depends on the access to an irrigation system (cf. chapter 6.1.1.1.).

A ***drumseeder*** is an agricultural machine that can be used for mechanical planting and thus reduces the amount of labours. In Manoor there is a similar machine for planting, which has not been called drumseeder. The use of a drumseeder is perceived controversial in Chandagalu. Some farmers are convinced about the utility of a drumseeder, especially with regard to the *"labour problem"* (P15), others are sceptical, because they heard that in certain cases *"no growth was happening"* (P19), thus they do not use it for their field.

Rumours are an important sources of information in Chandagalu and influence a farmers farm management decisions regarding the use of agricultural technologies (P19; P12), such as a biogas plant, a drumseeder, or a machine to harvest or the use of ash as manure (P20).

Table 13: Concepts of social cognitive map that are only occurring in Manoor.

Manoor		
Human assets		
Skills (3%)		
Social assets		
Agricultural department (1%)	Local farmer organisation (5%)	Reputation (7%)
Industry (2%)	Private dealer (1%)	RSK (11%)
Financial assets		
Insurance (2.4%)	Ratio card (1%)	
Physical assets		
Fisheries (5%)	Machine to prepare the land (3.5%)	Rice hull/ husk (8%)
Governmental shops (0.5%)	Machine to remove waste (1%)	Silicone (3%)
Machine for planting (2.5%)	Minerals (4%)	Uria and potash (2.5%)
Natural assets		
Groundnuts (7%)	Sea (4.5%)	Seasonality (6.5%)
Pulses (6%)		

Important assets (> 5%) in Manoor, which are not occurring in Chandagalu are *local farmer organization, reputation, RSK, rice hull/ husk, groundnuts* and *seasonality* (cf. table 13). A ***local farmer organization*** is a self-help group of farmers. Help in this sense, ranges from "*loans*" (P34), "*information/ knowledge*" about governmental schemes, optimized farm management practices or agricultural technologies (e. g. P34). Certain groups are only accessible if certain conditions are met, such as "*the interest to help people*" or having "*capital*" (P32).

Having a good ***reputation*** facilitates a farmer to have access to several assets, such as "*social status*", "*loans*", "*confidence*" regarding the future of agriculture and thus a certain satisfaction of being a farmer and being motivated to make efforts. But to have access to a good reputation a farmer has to actively "*inform*" himself, should be "*innovative*" and have the "*capability to work hard*" in order to have a good "*yield*" with the harsh climate-, soil-, crop-conditions in Manoor (P23, P32).

RSK is similarly than VC farm an institution that is providing "*information/ knowledge*" (P23), "*loans*" (P29), "*seeds*" (P22), "*minerals*" (e. g. P36) or "*technologies*"(P21). But not every farmer has access to RSK, for some "RSK is too far away" (P37) or other feel not "confident" to ask RSK for help, because they have "*a sort of an inferiority complex*" (P23).

Rice hull/ husk is the remaining part of the paddy plant that is left, after the production of rice. Rice hull/ husk is directly used as a substitute for "*manure*" (P21) or indirectly, by using the "*ash*" as "*manure*" (e. g. P31), produced by "*fish factories*"(P26), which use the rice hull/ husk for the production of their fish meals, or by "*rice mills*"(P25), which use the rice hull/ husk as fuel to boil the rice. Directly useable rice hull husk is only provided by certain rice types, such as white rice (P24). The ash which is indirectly obtainable by rice mills and fish factories is expensive and limited. Likewise for certain farmers it is not convenient to use the ash of the fish factories, because it is tied to the death of animals (e. g. P24).

Groundnuts are an important cash crop for Manoor, such as sugarcane for Chandagalu. While paddy is mostly produced for self-consummation, groundnuts are grown as additional income source (P33; P34). To produce groundnuts the land has to fulfill certain conditions, thus it should not be located within a flood area (P26).

Seasonality refers to the dictating of physical conditions, such as "*soil quality*" or "*climate*", which divides the year into different crop seasons. Seasonality thus is important for the livelihood of a farmer, as it influences its "*farm management*", available "*time*", etc. (e.g. P21, P25). Seasonality within the resilience map of Chandagalu is equal to the asset "*length of growing season*".

Table 14: High differences in values Chandagalu vs. Manoor (> 10%).

Human assets	
Independency	25.5 vs. 12.5
Trust	22.7 vs. 13
Physical asset	
Biogas plant	9.5 vs. 21
Technology	12 vs. 23
Irrigation system	15.5 vs. 8.5
Natural asset	
Soil quality	5 vs. 15.5

High differences in values have the assets *independency, trust, biogas plant, technology, irrigation system* and *soil quality* (cf. table 14). ***Independency*** in Chandagalu has a higher value than in Manoor. Independency on the one side appears to be preferable:

"Yes, I am happy […] I am working and earning for myself" (P20).

The access to independency in Chandagalu is perceived as being constraint in numerous ways, such as *"dependency on climate"* or *"soil conditions"*, thus it is not possible to diversify the crop (P4; P6). Independency as well is constraint by *"dependency on government"* and thus the *"arbitrariness of people who have the power"* (P1), *"dependency on machines",* because *"nobody has cattle anymore"* (P15) or *"dependency on labours"* for planting and harvesting (P9), etc. On the other side a certain dependency appears to be preferable, such as *"dependence on VC farm"*, because they are providing and limiting the amount of high quality seeds (P6), *"dependency on scientists"*, because their advice it supposed to increase the yield (P12), etc. In Manoor the reasons for non-accessibility to independencies were not perceived as numerous as in Chandagalu.

Access to ***trust*** is likewise more alterable in Chandagalu than in Manoor. Trust for instance, regarding to *"new technologies"*, *"political decisions"* or *"VC farm"* is dependent *"own experiences"*, *"rumours"* and *"believes"*, *"guaranty"* or *"refund"*, etc. Farmers in Chandagalu moreover made adverse or mixed experiences regarding *"new technologies"*, *"political decisions"* or *"VC farm"*.

"We already have experienced that for the water irrigation. We already went through the losses of one year and it is actually very difficult for us at the moment" (P1).

"They (government) are not completing any project which they take off. They are all blind projects. They are done only for the benefits for a few people" (P3).

"Yes, we do lose the fate, if something like this happens (technology failures). Then it becomes very difficult to trust them" (P9).

"Also the VC farm people here are helping us, by getting a better yield, which is not happening by a long time, but now it is increasing" (P1).

"It is very difficult to follow the way of the VC farm they tell you to do farming, because you need […] to many labours to do this job" (P13).

Differently in Manoor, where farmers moreover trust in local based governmental subdivisions, such as RSK, or new *"technologies"*. However governmental decisions generally are likewise not improving the trust of farmers in Manoor.

"100%. They have newest technologies at a subsidised rate and training camps" (P23).

"Any technology which has to be implemented has to be experimented and we have to be ready to face the consequences of it. If it is profit it is fine, if it is a loss it is fine" (P23).

"I grow my own seeds and the seeds I buy them from RSK. I do not buy them from anywhere outside, because I don't trust" (P32).

"The government policies. We are not getting the right schemes. They are giving one rupie rice, they are looking only for one kind of the community, […] those people who are voting for them" (P25).

In Manoor the utility of ***biogas plants*** is not as controversial as in Chandagalu, were most of the farmers stopped using biogas plants. Biogas plants in Manoor are used for *"cooking"* (P25), thus as *"energy"* (P22) source, but as well they use the remaining slurry, as *"manure"* (P27) for the field. For this reason farmers in Manoor are more motivated to repair the biogas plant, in cases they failed or were leaking. This is not the case in Chandagalu, were the utility of biogas plants are questioned:

> *"I don't use it, because there is no place. And also it is not doing well. It failed in this place. There are a lot of complaints" (P9).*

> *"The government came up with a scheme and I got it for a subsidised price. You need to have place and you need to have cows. If it is there, than you can use it" (P17).*

> *"If you do biogas, than your cow dung becomes a waste. The good things, the nutrients of the cow dung […] are removed from it" (P11).*

Technology in both villages is generally perceived as being beneficial, if they provide a chance to replace labours (cf. chapter 6.1.). Whereas in Chandagalu farmers generally have the possibility to access machines, if they *"trust"* (P9) in their utility and have enough available *"capital"* (P13). In Manoor, the utility of agricultural machines is not per se given, because of physical and economic constraints (cf. chapter 6.1.2.1).

Irrigation systems are an important topic in Chandagalu, hence they highly depend on artificial irrigation, provided by *"canals"* (P13)*, "drip irrigation"* (P1) or *"wells"* (P17). The limited water availability in Chandagalu affects the *"diversity of crops"* (P13), that are possible to cultivate, their decision either to grow sugarcane or not (P7) or in the worst-case their *"yield"* and thus *"income"* (P4).

> *"We have to depend on the irrigation, the canal. That's why we are growing this. But if we had water, like the pumps and other things, we would have grown vegetables like beans […]"* (P13).

In Manoor farmers mostly depend on natural irrigation (e. g. P28). They are also struggling with too much water, which comes with the proximity to the sea spoiling the soils (P21).

Soil quality is crucial in both villages, however in Manoor there are more factors that are perceived to influence the quality of soil. Whereas in Chandagalu *"farm management"* decision, such as over-usage of *"fertilizer"* and unsufficient use of *"manure"* or lack of *"irrigation systems"*, etc. are perceived to influence the soil quality, the soils in Manoor are more influenced by *"machines"*, that compress the soil structure, by salted water of the *"sea"*, over-use of "*fertilizer"*, etc. However in Manoor more strategies were mentioned how to improve the soil quality, such as usage of *"ash"* or *"charcoal"* (P22), *"minerals"* (P3; P16), organic farming, thus use of less *"fertilizer"* (P32), etc.

Especially the last outlines about significant differences within the two systems illustrate that farmers in Manoor are more solution-oriented, in a sense, that they actively seek solutions to improve their farm management to improve their life. This is manifested in their tendency to be more interested in advices from agriculture extension institutions (RSK), their strong interest in the application of new technologies and making use of these technologies in various manner (e. g. biogas plants) or their interest in using different soil quality enhancement measures.

Farmers in Chandagalu are more demanding, thus they tend to claim that the government does not take enough effort to change the delicate financial situation of the farmers. However, their tendency to "claim" is possibly based on their more negative experiences they have made with new technologies (e. g. machine of harvesting, biogas plants), political decisions (e. g. canal) or advices of agricultural extension institutions that were perceived as being too difficult to follow.

6.2. Biochar system implementation scenarios

An implementation of a biochar system might alter the resilience of the system and the vulnerability of the individuals. To assess the resilience and individual vulnerability a hypothetical small-scale-, respective large-scale biochar system was "implemented" within the pre-defined structure and function of the socio-ecological systems of the baseline scenario of Chandagalu and Manoor. By analysing how a hypothetical implementation of a biochar is altering the socio-ecological system its impact on the resilience and individual vulnerability have to be determined.

6.2.1. Small-scale vs. large-scale scenario

The results of the small-, and large-scale scenario are based on a literature review (cf. chapter 2; annex H) and thus are therefore hypothetical. In cases of a large-scale implementation where a biochar system is implemented in sugar factories or rice mills, the concrete impact of an implementation on the community might be lower than for a small-scale implementation. This is because a small-scale implementation, where a biochar system is supposed to be directly implemented into a community, is demanding generally a higher allocation of certain assets by the farmers.

Table 15: Relative change of asset centrality caused by implementation of a small-, respectively a large-scale biochar system (+ = centrality increases by less than 5%; ++ = centrality increases by more than 5%; ++, + = alteration of centrality is higher).

Asset	Small-scale	Large-scale
Farm management	++	+
Labours	++	++
Trust	+	+
Government	+	+
Land rights	+	+
Market	+	+
Scientists	+	+
Capital	+	+
Income	+	+
Market prices	+	+
Energy	+	+
Fertilizer	+	+
Irrigation system	+	+
Land size	+	+
Manure	+	+
Transportation	+	+
Climate	+	+
Land	+	+
Soil quality	+	+
Sugarcane/ paddy	+	+
Yield	+	+

Table 15 illustrates the alteration of centrality of assets, which are influenced by an implementation of a biochar system, either because they were necessary for an implementation or because they were altering specific assets within the system. In a small-scale implementation the alteration for certain assets is, as indicated, higher than for a large-scale implementation. Assets that are dominantly affected by a small-scale implementation are *farm management and labours.* Centrality of *government, land rights, scientists,* and *capital* are generally more altered due to a small-scale than for a large-scale implementation. For a large-scale implementation the centrality of *labours* remarkably increased and is supposed to be also more altered than in a small-scale implementation.

However the concrete impact of a biochar system on a socio-ecological system can only be understood by an analysis of the potential alteration of function and structure of the system. An implementation might alter the system's function simultaneous, in a negative and positive way. This in turn influences the function of the system, which may has to be re-established in order to be resilient. Otherwise an implementation might influence the vulnerability of an individual, who is dependent on the access to relevant assets for an implementation of a biochar system or use of a biochar. An alteration of the relative importance of certain assets within the map, accordingly may influence the structure of the system.

6.2.1.1. Potential alteration of resilience of the socio-ecological systems

An implementation of a biochar system might results in a certain reinforcement of assets that are influencing the system. Assets that are affected by a small-, and large-scale implementation of a biochar system in **Chandagalu** are *farm management, labours, government, irrigation system, income, climate, yield, manure, fertilizer, soil quality and energy* (cf. chapter 2).

Regarding their influence within the baseline scenario, *farm management, labours, government, irrigation system, income, climate and yield* (cf. figure 11; baseline-outdegree > 10%) are relative important assets that are influencing the system. A reinforcement of the influence of these assets caused by a small-, or large-scale implementation, hence is supposed to may alter the system more significantly than the other assets, such as *manure, fertilizer, soil quality and energy.*

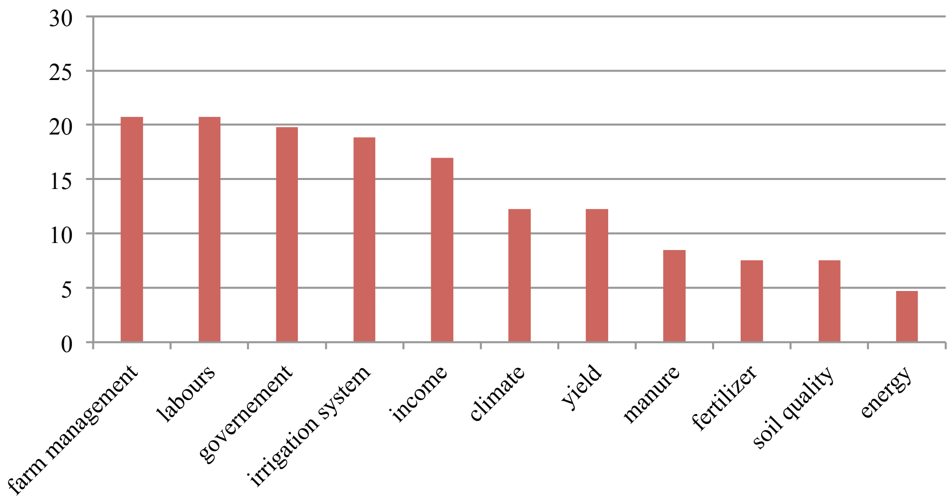

Figure 11: Potential for alteration of resilience in Chandagalu (standardized outdegree in %).

A sustainable implementation of a biochar system therefore especially needs to consider, that assets with a relative high impact on the system are minimal or solely positive influenced. A sustainable biochar system implementation in Chandagalu accordingly should especially fit into common ***farm management*** activities, it should be utilised without many ***labours***, thus availability or shortness of labours is a crucial livelihood constraint in Chandagalu, the ***government***al regulatory institutions should be liberal, but in financial terms supportive, the ***irrigation system***, or the water availability should not be tangent and the ***climate*** and the ***yield*** should not be affected negatively (cf. chapter 6.1.1.; outlines of table 14).

In **Manoor** assets that are crucial for the resilience of the socio-ecological system are *government, farm management, labours, soil quality, climate, income* and *yield* (cf. figure 12; baseline-outdegree > 10%). Less important are *irrigation system, fertilizer, manure* and *energy.* An alteration of the former ones might alter the resilience of the system more than the latter.

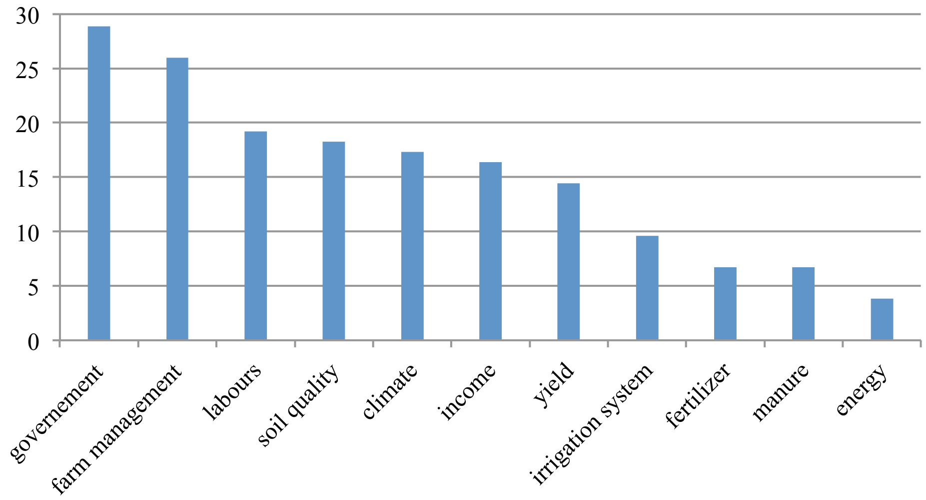

Figure 12: Potential for alteration of resilience in Manoor (standardized outdegree in %).

In Manoor major adaption barriers accordingly were non-fitting into ***farm management***, non-availability of labours, negative impacts on ***soil quality,*** **climate,** ***income*** and ***yield***. ***Governmental*** influence on the livelihood of farmers is generally high, but as illustrated above, a potentially increase of governmental influence may not be perceived as strictly negative, as it may be in Chandagalu (cf. cf. chapter 6.1.1.; outlines of table 14).

6.2.1.2. Potential alteration of individual vulnerability within the socio-ecological system

In order to assess the alteration of the individual vulnerability the access of assets, that are important for an implementation of a biochar system within the village or regarding an application of biochar produced on large-scale basis, have to be analyzed. To identify this access, the indegree of these assets, determined in the baseline scenario, indirect indicate its constraints and possibilities.

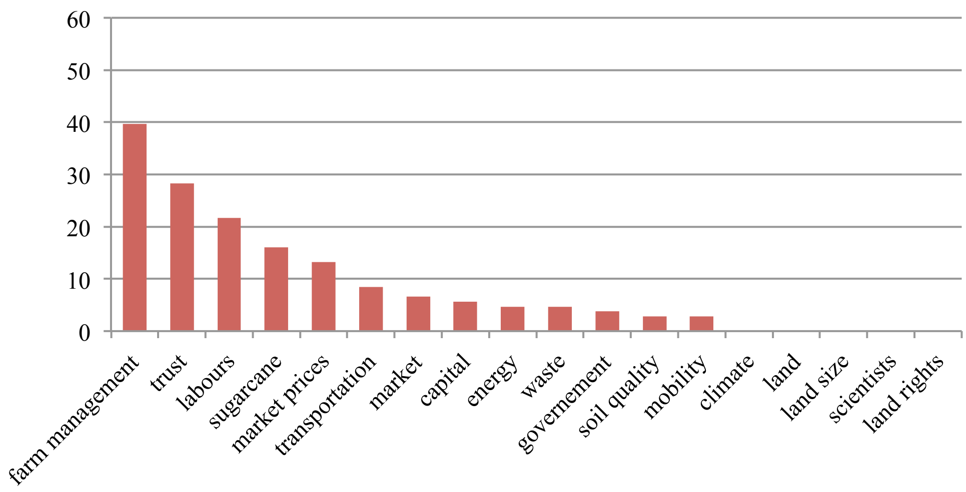

Figure 13: Potential for alteration of vulnerability in Chandagalu (standardized indegree in %).

In **Chandagalu** access of *land, land size*, *land rights*, *scientists* and *climate* is not alterable. Whereby access to *soil quality, transportation, market, capital, energy, waste, government, mobility* are moderate and *farm management, trust, labours, sugarcane* and *market prices* are highly alterable (cf. figure 13).

Adaption barriers based on the individual vulnerability, accordingly are moreover given by the differences in accessibility and non-accessibility of ***land-rights***, the geographic location of the ***land*** or ***land size***. Whether a farmer owns a suitable land to use for the biochar production or for biochar application, or not. ***Climate*** similarly is not directly accessible, likewise ***soil quality*** that is minim alterable. Biomass acquirement regarding this fact, thus strongly depends on climatic and soil-conditions.

Scientists in this scenario are relevant, because depended on their capacity to construct a pyrolysis unit that enables to coproduce bioenergy products for small-scale utilisation (cf. chapter 2.3.), might increase the value of a pyrolysis unit within a village, regarding the fact, that access to ***energy*** is generally limited in Chandagalu (P1). However farmers directly have no access to scientist's decisions.

Transportation and ***mobility*** are other important assets that influence a successful implementation. But access to transportation and mobility are minim alterable by the farmers (P15). Transportation costs to be mobile in most cases are perceived as being high, thus mobility of farmers is generally strongly constraint and therefore may limit a successful implementation of a biochar system.

The access to ***market*** is mostly controlled by external factors, such as local political decisions regarding protectionism or free trade (P5; P11). Thus the establishment of a biochar, bioenergy market or potential carbon market will likewise strongly be regulated by the government. Accordingly, the utility of a biochar system or biochar depends on the provision of accessible market structures.

Important for a small-scale biochar system, but as well for the acquirement of biochar as soil enhancement product is ***capital***. Access to capital however is difficult for the farmers to generate, because the generated income is usually entirely used for household and farm management based expenditures (P14; cf. chapter 6.1.1.1).

Access to ***farm management*** is highly alterable, as a consequence, that dependent on the available access possibilities of the farmers to freely decide how to manage their farm, a biochar system may be easy implementable or not (cf. 6.1.1.2). The most constraining factors that influence the access to a free farm management decisions are "irrigation system" (P14; P17; P18), "labours" (P2, P8) and "market prices" (P17, P6, P14). Thus especially ***labours*** and ***market prices*** are crucial adaption barriers regarding an implementation of a biochar system both small- and large-scale.

Sugarcane as potential biomass providing plant generally are accessible by almost every farmer, thus it represents the most cultivated cash crop within the area of Mandya, respectively Chandagalu. However, this access is limited to water accessibility. In times of water scarcity farmers in Chandagalu prefer to cultivate paddy, instead of sugarcane (cf. chapter 6.1.4.). The remaining bagasse, or ***waste*** that is left after sugar or jaggery production of sugarcane is more difficult to access. Bagasse is accumulated at the places of production, hence at sugar factories or jaggery houses. Dependent on the transportation or mobility abilities of the farmers this bagasse is easy or less easy accessible.

Further ***trust*** into new technologies is crucial for an implementation, but as previous illustrations are indicating, farmers of Chandagalu generally are sceptical regarding new technologies, caused by negative experiences (cf. chapter 6.1.4.)

In **Manoor**, the picture is similar. Access to *mobility, land rights, land* is not *alterable*. *Scientists, land size, market, climate* and *government* are little alterable. *Energy, waste, transportation, capital* are moderate alterable and *trust, soil quality, paddy, market price, labours, farm management* are highly alterable (cf. figure 14).

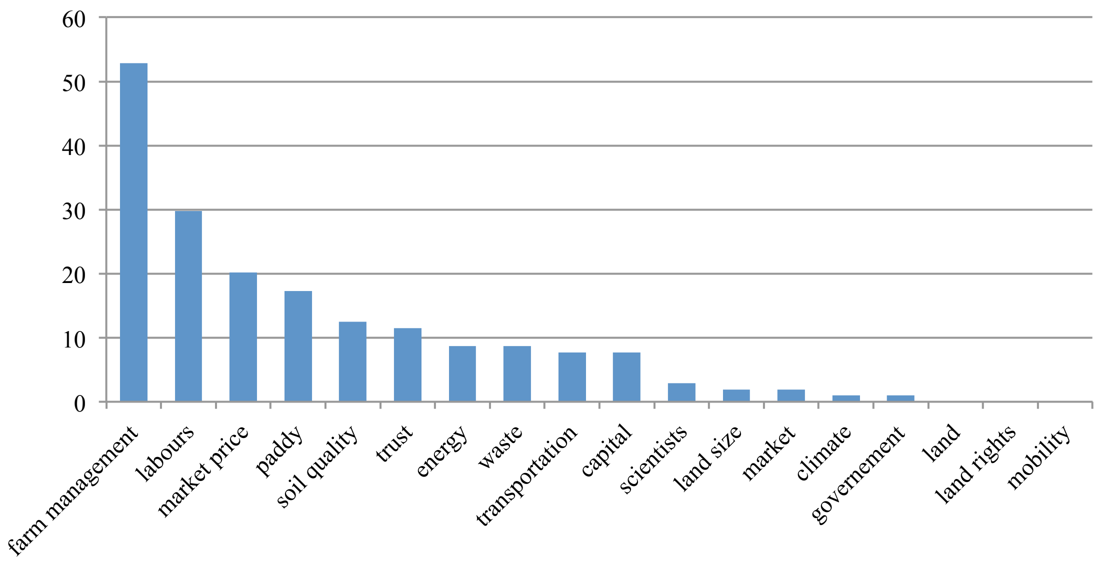

Figure 14: Potential for alteration of vulnerability in Manoor (standardized indegree in %).

Non-alterable access to ***mobility, land rights*** and ***land*** thus is determining an implementation of a biochar system in Manoor on the individual level. Since access to ***scientists, land size, market, climate and government*** are little alterable by the farmers, these conditions either have particularly be respected, such as climate and the possible cropping production systems, or they have to be made accessible by external forces. Thus scientists should provide pyrolysis units, in order to enable an efficient production of biochar and its co-products, or market access should be provided by the government.

Energy, waste, transportation, capital are moderate alterable. This indicates, that access to waste or rice hull husk is difficult to assess for the small-holding farmer. Rice hull husk is accumulated at the rice mills and not within the villages (cf. chapter 6.1.4.). Taking into account the unprofitable road infrastructure in Manoor it is assumable that it is especially in Manoor difficult to acquire biomass as feedstock basis. Access to capital is for most of the farmers difficult, so they are satisfied with being able to manage the household and the farm, otherwise they have to apply for a loan (P22).

Access regarding the assets ***soil quality, paddy, market price, labours, farm management*** and ***trust*** is highly alterable. This does not indicate that farmers automatically have access to these assets. Farmers in Manoor have developed different strategies to gain access to *soil quality* (cf. chapter 6.1.4). This indicates that the quality of soil is a crucial issue that is concerning their livelihood, but not every farmer is having access to assets, which are necessary to improve soil quality. *Paddy* is the main food crop of farmers in Manoor, therefore generally all farmers are cultivating paddy, depending on their access to subsidised seeds or fertilizer and manure. The paddy yield strongly depends on physical conditions, such as rainfall and salted water. The fewer yields, the lower is the possibility to provide biomass. Farmers can only influence the *market price* by storing their yield (cf. chapter 6.1.2.1.). Other than that, they cannot directly alter the market prices of paddy, agricultural products such as fertilizer or manure (P14). *Labour* availability is low in Manoor, because of governmental support schemes, advancing industrialisation and migration to the city. Access to labour thus is highly alterable, which makes it difficult for the farmers to acquire them. Similar access to *farm management decisions* is highly alterable. As illustrated in chapter 6.1.2.1. farm management depends on several assets, thus not every farmer might be able to decide freely whether to make use of a biochar system or biochar as soil amendment. *Trust* is essential for an implementation of a new technology. In Manoor access to trust is highly alterable, but as illustrated in chapter 6.1.4. in most cases existent.

6.2.1.3. Similarities and differences

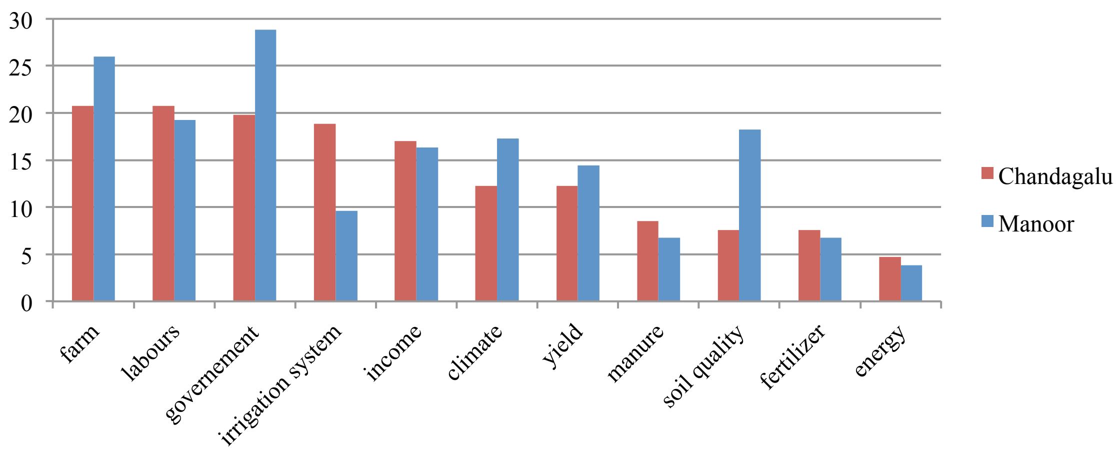

Figure 15: Comparison between potential for alteration of resilience in Chandagalu and Manoor (standardized outdegree in %).

A comparison between Chandagalu and Manoor (cf. figure 15) and how assets that are influenced by an implementation of a biochar system are influencing the function or resilience of the system are indicating which assets are generally and which assets are village-specifically important.

General assets that are important in both villages are ***farm management, labours, government***, ***income*** and ***yield***. The relevance of *irrigation system* has to be considered specifically in Chandagalu. Otherwise the impact of the ***climate*** and ***soil quality*** is crucial in Manoor.

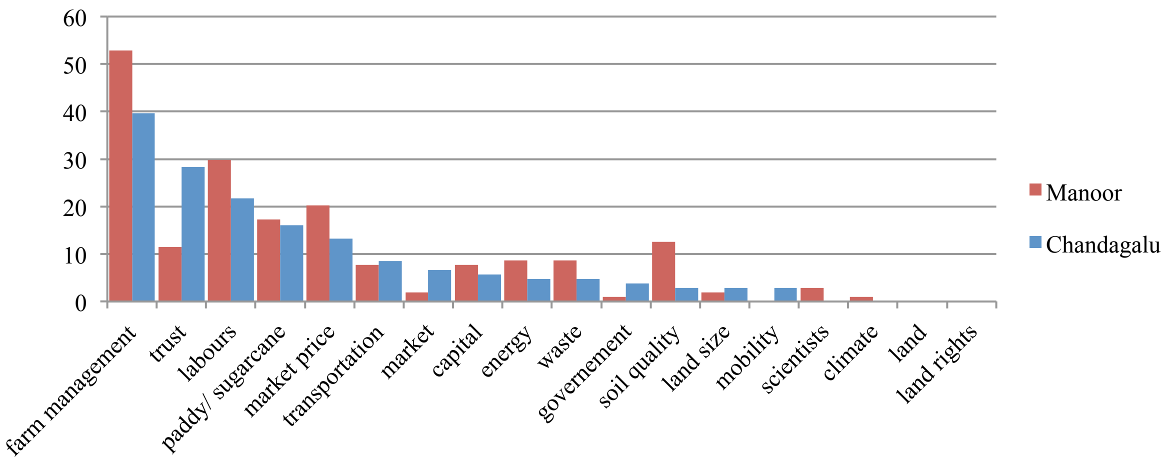

Figure 16: Comparison between potential for alteration of vulnerability in Chandagalu and Manoor (standardized indegree in %).

A comparison of the two villages regarding the individual vulnerability of the farmers (cf. figure 16) reveals which assets have to be considered generally and village-specifically regarding an implementation of a biochar system. Access to ***land rights, land, climate, scientists, mobility, land size*** and ***government*** is in both villages barely given. These are the assets that have to be considered especially, thus they are strongly framing a successful implantation. Similar access to ***transportation, market, capital, energy*** and ***waste*** is generally difficult to guaranty. Access to ***paddy*** or ***sugarcane*** as feedstock for biochar production is generally given in both villages, however is depending especially on climatic conditions. Access to ***trust*** is more difficult in Chandagalu than in Manoor. Otherwise access to ***market prices, labours*** and ***farm management*** in Manoor is more alterable than in Chandagalu.

6.2.2. Worst-case scenario

A worst-case scenario occurs if relevant assets that are needed for a farmer's livelihood were negatively influenced by the implementation of a biochar system. Depending on the adaptive strategies of a farmer, the impact of risk might be decreased or reinforced.

6.2.2.1. Worst-case scenario in Chandagalu

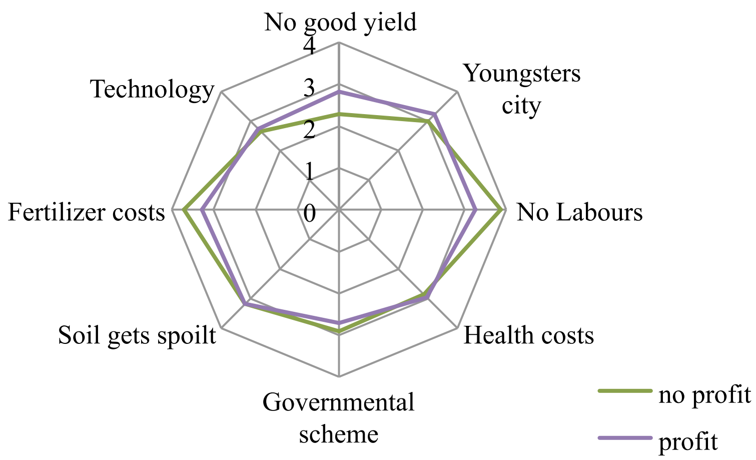

Figure 17: Rating of worst-case scenario Chandagalu (1 = none; 2 = low; 3 = medium; 4 = a lot; 5 = huge).

The results of the questionnaire show, that all assets are perceived as having a relevant impact on the livelihood of a farmer (cf. figure 17). The impact is generally moderate in a scenario where a farmer is able to generate profit, whereby in a scenario where a farmer is not able to generate profit, the impact of having *"no labours"* and *"increasing costs of fertilizer"* is higher. The importance of the asset "no good yield" is decreasing.

There were several reasons mentioned for the occurrence of these risks, but as this would repeat the previous illustrations in chapter 6.1. they are not considered additionally. The following outlines are focusing on the strategies of the farmers regarding the occurrence of these risks. Not all strategies are described in detail, the illustration moreover focuses on the most mentioned strategies[8].

Having ***"no yield"*** at the end of a production season has a serious affect the livelihood of a farmer. As described in chapter 2.3. the interplay between soil-climate-crop response and suitability of biochar characteristics are crucial for the outcome. A worst-case would be that no yield would happen caused by the application of biochar. Accordingly it is important, that farmers have strategies to mitigate this risk. The highest mentioned strategy to mitigate the impact of *"no good yield"* was to take a *"loan"*, others would *"test the soil"*, use *"high quality seeds"* or *"more manure"* and more *"fertilizer"*.

"Youngster move to the city" and ***"not enough labours"*** refer to the need of labour force to successfully implement a biochar system, whether large-scale or small-scale. The impact of *"not enough labours"* are rated lower in a scenario where profit is higher, than in a scenario where profit is lower. Possibly the farmers were linking a non-profitable year with the non-availability of labours. Three dominant strategies to overcome labour shortness that were mentioned are *"give higher wages"*, *"do the work by our own"* and get *"support of family members"*. The latter strategy however is insecure, thus youngsters decide to migrate to the city, in expectation of getting a better income, which is perceived by the farmers as not possible within an agricultural context. Strategies for farmers to replace these working forces are: *"take extra labours"*, *"work more"*, *"use machines"* or get *"support of neighbours"*.

[8] All mentioned reasons and strategies are documented in the annex I of this thesis.

There are certain concerns that emission of biochar production or fugitive biochar loss while transporting would have negative effects on health (cf. chapter 2.4.), which consequently would have an impact on ***"health costs"***. The most mentioned strategy to overcome *"health costs"* is to take a *"loan"*.

An implementation of a biochar system is tied to legislative measures, thus governmental interventions. The interviews have revealed, that many farmers are sceptical regarding governmental schemes, because they perceive the government as being corrupt and uninterested regarding farmers concerns. Strategies to overcome ***"unsuitable governmental schemes"*** are *"doing nothing, because we are used to it"* and *"striking"*.

"Soil gets spoilt" is a similar risk than having *"no yield"*. However *"soil gets spoilt"* is referring to a possible negative long-term effect, that is potentially given caused by the application of biochar to soil, thus biochar is highly recalcitrant. Farmers' strategies regarding *"soil gets spoilt"* were similar than for having *"no yield"*, such as stopping the application of chemical fertilizer and apply *"home-made manure, cow dung and compost"*, *"soil test"*, etc.

"Increasing costs of fertilizer and manure" would affect an implementation of a biochar system, thus several studies have shown, that the highest effect on yield output regarding biochar application, is happening if additionally fertilizer and/ or manure is added (cf. chapter 2.3.). Consequently the costs of fertilizer and manure are relevant for a high yield. In a scenario where no profit is possible, farmers rated its relevance even higher, indicating, that the use of manure and fertilizer were perceived as crucial for a good yield, thus farmers income. Strategies regarding continuously increasing fertilizer and manure costs are *"subsidies"*, *"using home-made manure/ dung"* and *"taking a loan"*.

A ***"suitable technology"*** is adapted to the needs of the farmers. Experiences of the farmers revealed that new agricultural technologies often were not applicable, thus were not correlating with their needs (e. g. biogas plants, drumseeder; cf. chapter 6.1.). In case of a biochar system implementation, trust and acceptance of the farmers is critical. However any new technology carries the risk of failure, especially if the context is that important as it is for biochar. Consequently it is important, that farmers have certain strategies to overcome the risk of failure. In Chandagalu the following strategies were mentioned: *"using traditional methods", "using labours"* or asking *"Krishi Mela"* or *"authorities"* for help.

6.2.2.2. Worst-case scenario in Manoor

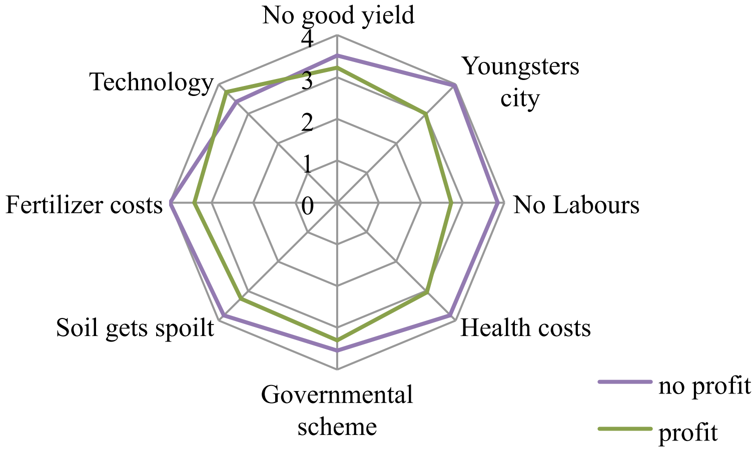

Figure 18: Rating of worst-case scenario Manoor (1 = none; 2 = low; 3 = medium; 4 = a lot; 5 = huge.

The Results of Manoor show a different picture (cf. figure 18). All assets are moderately important in a scenario when profit is possible, despite the asset *"technology"*, *"governmental scheme"* and *"fertility"* were ranked higher than medium. If no profit is possible all assets were ranked as having a high influence on the livelihood of a farmer. The impact of technology is lower in a scenario with no profit, than in a scenario with profit.

Facing the risk of having ***"no yield"*** farmers in Manoor take a *"loan"*, *"ask RSK"* for advice and use *"manure and compost"*, instead of chemical fertilizers. For shortages of human resources, caused by ***"no labours"*** or ***"youngsters move to the city"*** farmers of Manoor are having the following strategies: *"give higher wages to the labours"*, *"take governmental aid"*, get *"support of family members"* or take a *"loan"*. To keep the children in the village, they try to *"convince them about the advantages of agriculture"*. ***"Health costs"*** are managed by going to a *"governmental hospital"*, were they get medical care at least for a subsidised, low price. Otherwise they make use of a *"health card/ insurance"* or take a *"loan"*, etc. ***"Governmental schemes"*** are generally not perceived as being unfair, reasons for their failure are *"lack of information transfer"* or *"unaware politicians"*. To overcome these difficulties farmers insist to enhance the *"information transfer"*, otherwise the take a *"loan"*. Regarding the risk of ***"soil gets spoilt"*** farmer would use *"high quality fertilizer"*, *"create a canal"* to deflect the salted water, which is perceived as being the reason for spoilt soils. Otherwise they would make a *"soil test"*. ***"High fertilizer or manure costs"*** were managed by either use *"home-made manure/ compost"* or taking a *"loan"*. ***"Unsuitable technology"*** according the farmers, should be avoided by increasing the *"information transfer"* and by using solely technologies that have a *"high quality"*.

6.2.2.3. Similarities and differences

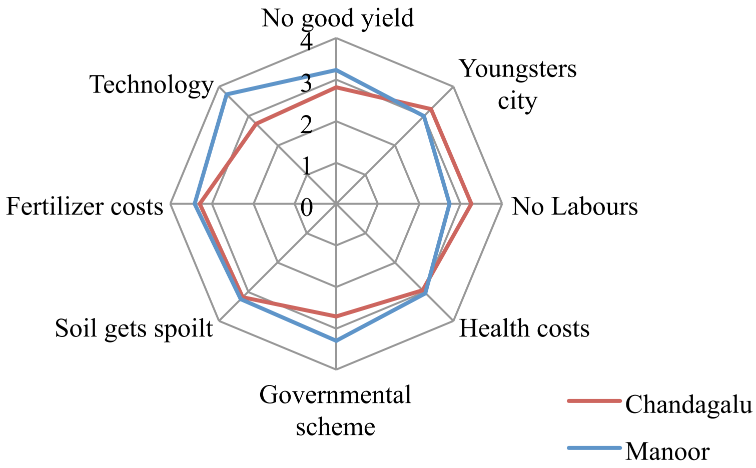

Figure 19: Similarities and differences of worst-case scenarios with profit (1 = none; 2 = low; 3 = medium; 4 = a lot; 5 = huge).

In a worst-case scenario, where it is possible to generate *"profit"* for the farmers, the impact of scenarios is almost similar in both villages (cf. figure 19). Except *"governmental scheme"* and *"unsuitable technology"*, which both were rated higher in Manoor as in Chandagalu.

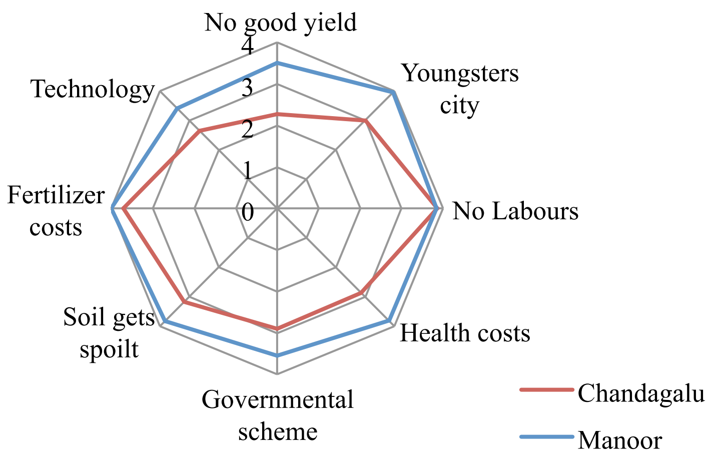

Figure 20: Similarities and differences of worst-case scenarios without profit (1 = none; 2 = low; 3 = medium; 4 = a lot; 5 = huge).

The *„no profit"* situation (cf. figure 20) clearly reveals a difference between the two villages. The rating of *"technology"*, *"no good yield"*, *"youngster move to the city"*, *"health costs"*, *"governmental scheme"* and *"soil gets spoilt"* are lower in Chandagalu than in Manoor. *"Fertility"* and *"labours"* are equally important.

Overall mentioned strategies to overcome these risks were generally similar in both villages. In most cases farmers would take a *"loan"*. To manage human resources shortages, they would give higher *"wages to the labours"*, *"do the work by their own"* or take the help of *"family members"* or *"neighbours"*. Regarding soil quality and fertility issues, they would use *"home-made manure"* or let the *"soil tested"*. In both villages regarding the farmers, the *"information transfer"* should be enhanced. In this sense strategies of farmers are strongly dependent on external conditions, and are barely controllable by the farmers themselves.

7. Synthesis and discussion

The results and analysis part has shown, that access to relevant assets regarding an implementation of a biochar system in both villages is predominantly constraint and heteronomous and that farmers dependencies would increase in case of a negative outcome, because strategies are limited and strongly depended on external conditions. In this chapter the general and village-specific significance of these results for a biochar system implementation will mainly be the subject of discussion. Further it will be discussed under which conditions a biochar system implementation might be sustainable.

The synthesis and discussion is additionally confirmed and complemented by literature, but also by the results of the focus groups and the expert interviews. The statements of the expert interviews are labelled with a capital E.

7.1. General significance of adaption barriers

A biochar system implementation, whether small-scale or large-scale, is confronted by certain adaption barriers. Adaption barriers in this sense exist due to the initial resilience of the system, or how the system is maintaining its function caused by various perturbations and disturbances. Otherwise they are manifested in the different individual vulnerabilities or the different access farmers have to assets and/ or strategies that might be relevant for an implementation. The results and analysis part have revealed general or for both villages valid adaption barriers regarding a biochar system implementation. In the following illustration, these adaption barriers were distinguished in social, economic and ecological adaption barriers. For each identified adaption barrier its significance for a sustainable biochar system implementation will be discussed.

7.1.1. Significance of social adaption barriers

An implementation of a biochar system alters the influence of government, labours and farm management on the system-level and increases the importance of labours, trust, scientists, farm management and government on the individual-level. Based on the reaction or the available possibilities of the farmers, the impact will change or reinforce the resilience of the system or the vulnerability of the individual farmers.

The results of both villages reveal that on the one side ***government*** is having a specifically high impact on the villages. On the other side access to government is very constraint. The influence of the government in both villages is perceived as being more negatively than positively, because relevant financial support is general available, such as subsidies, loans or refunds, but not per se guaranteed. Furthermore market prices of agricultural input products are increasing, whereas market prices of agricultural output products are decreasing. Farmers therefore feel undervalued and not understood regarding their concerns. They claim that the government should fix the prices, in order to guaranty the survival of the farmers. However, the analysis of the individual vulnerabilities has shown, that the government or political decisions are not accessible or influenceable by the farmers. Furthermore the worst-case scenario revealed, that strategies regarding unsuitable governmental schemes are limited, such as “striking” or “doing nothing, because we are used to it”. Farmers in Chandagalu and Manoor in this sense are powerless and are dependent on governmental decisions.

> An implementation of a new agriculture technique consequently involves rules (cf. chapter 2.2.). These are commonly set or constraint by regulatory institutions, in this sense by the government or governmental subdivisions. In the case of an implementation of a biochar system, supplementary governmental

> influence might reinforce this perceived constraining impact on the livelihood of the farmers and reinforces the dependency of the farmers. This might have an influence on the farmer's willingness to adapt. Therefore it might be worthwhile to think about how an implementation of a biochar system might be realisable within a constructive setting, were farmers and responsible authorities collectively develop rules of production and/ or application.

The availability of ***labours*** is another relevant social factor that might prevent a successful implementation of a biochar system. Labours are needed by the farmers for several livelihood activities, such as planting or harvesting. The accessibility however is constraint due to labour shortage and high labour wages. Farmer's reaction regarding this labour shortage depends on their access to support of family members, friends or neighbours. However migration to the city is affecting both labour availability and support of family members, therefore a farmer is facing a dilemma. An alternative is the usage of agricultural machines, such as drumseeders or machines for harvesting (cf. chapter 6.1). However the land of the farmers is fragmented and road conditions are critical, which makes it difficult for farmers to reach their land efficiently with these machines (cf. chapter 6.1.4.)

> Regarding an implementation of a biochar system labour shortage therefore critically influences its success. It indicates, that the need of labour force within biomass, production and application phase of a biochar system (cf. chapter 2.2.) have to be minimized specifically.

The influence of ***farm management*** decisions in both villages is strongly shaping the function and structure of the system. Access to unconstraint farm management decisions on the one side is highly alterable and on the other side is not accessible by every individual farmer. An implementation of a biochar system however requires a certain re-organisation of the farm management. As a consequence only these farmers may make use of a biochar system or biochar as a soil amendment, who are in a position to make more or less free farm management decisions. The results of the focus group decisions exactly revealed this consequence (cf. annex J). Thus a biochar system might not be a "money making system for a small-scale farmer", because he/ she does not have enough initial input factors available, such as amount of yield as feedstock source, capital, labours, time, etc. (cf. annex J). With regard to the high resilience-shaping influence of farm management decisions on both systems, an alteration of this asset may consequently alter the systems profoundly.

> A successful implementation of a biochar system accordingly has to consider ways, how farmers with less opportunities or access to critical assets as well can be provided with the possibility to gain profit. Otherwise it increases the inequity level within the village (cf. annex J). An enhancement of possibilities for less privileged farmers might be by improving the access possibilities to certain assets by cooperation. The focus groups of both, the students and the farmers showed similar results. Some of the members of the focus group indicated the success of the milk society or sugarcane organisation. However both of these organisations are organised by the government. Previous expert interviews with local scientists revealed, that setting up cooperation of farmers might be difficult to realise, since management problems would certainly arise (E1; E4).

Access to ***scientists*** is low. However, a scientist in this sense is responsible for the development of a biochar system that is suitable for these specific socio-ecological systems. This includes a pyrolysis unit that enables farmers to produce a biochar product with characteristics that are suitable for their system-specific climate-soil-crop system and ideally enables him/ her to produce bioenergy co-products (cf. chapter 2.2.; 2.3.). Likewise it includes the determination of application method and rate (cf. chapter 2.3.). The results of both villages show that farmers generally trust, and in this sense depend on what scientists are advising them (cf. chapter 6.1.). The results of the worst-case scenarios indicate that "unsuitable technologies" are profoundly affecting the livelihoods of the farmers, thus farmers generally require technologies that facilitate their farming-based livelihoods (cf. chapter 6.2.3.). But in many cases, farmers perceive these technologies as not suitable, either because they are not affordable, not suitable or reachable for their lands, or because they alter assets negatively that are crucial for their livelihoods, such as soil quality, manure or feedstock for their livestock (cf. chapter 6.1.)

> An implementation of a biochar system accordingly should involve farmer's traditional farm management practices. Farmer's suggestions in both villages regarding an enhancement of the suitability of technologies, is an improvement of the "information transfer" (cf. chapter 6.2.3.). In their view, scientists or more specifically agricultural extension services should provide better and right-timed information about new technologies. For a development of a suitable technology, however it is important to not only improve the information-transfer towards scientists to farmers. Information transfer should moreover be bi-directional, thus a development of a new technology, such as a biochar system, should be carried out in close co-operation between scientists and farmers.

The results have shown that access to ***trust*** varies between and within the systems (cf. chapter 6.1.4). Trust is particular dependent on the kind of information source and accordingly the experiences made with the specific information source. Government on the one side is generally not perceived as being trustful, thus promises were neglected and no profound attempts to change the delicate situation of the farmers were effectively reaching the farmers. VC farm and RSK, as local representatives of the agricultural governmental department, on the other side, were perceived by the most farmers as helpful (cf. chapter 6.1.4.). However believes and rumours within the community are shaping the willingness of farmers to get help by the VC farm or RSK. The provision of guaranties or refunds otherwise are affecting trust positively (cf. chapter 6.1.).

> Regarding an implementation of a biochar system it is crucial by whom the initiative is started. To enhance trust it might be necessary to provide guaranties or refunds for cases of failure (cf. annex J).

7.1.2. Significance of economic adaption barriers

Economic adaption barriers are mostly identified on the individual level. Individual access to relevant economic assets regarding an implementation of a biochar system is either low to moderate or highly alterable by external forces.

The feasibility of an implementation of a biochar system is determined by the individual access to certain economic assets. These are land rights disposal for a place for biochar production and of suitable, not excessive fragmented land for biochar application (E1), mobility or transportation possibilities, further capital availability, market access, waste or feedstock and energy availability and relative affordable market prices. Access to ***land rights***, ***land*** and ***mobility*** is low to inexistent. Accordingly these assets are critical basic conditions that previously have to be fulfilled for a biochar system implementation. ***Transportation, capital, market, waste*** and ***energy*** are moderate accessible (cf. chapter 6.2.1.2.)

For an implementation of a biochar system it might be crucial to determine how access to these assets can be facilitated. This could include considerations about road infrastructure improvements or otherwise a development of a mobile and handy biochar pyrolysis unit (cf. annex J). In Chandagalu and in Manoor feedstock acquirement might be difficult for small-holding farmers, since bargasse and rice-hull husk are accumulated at the places of sugar, respective jaggery and/ or rice production (cf. chapter 6.2.1.2.). Capital acquirement by most farmers might only be possible in form of loans, which will increase the dependence and insecurities of the farmers (cf. chapter 6.2.3.). Regarding a small-scale biochar implementation it might be fruitful to think about the establishments of cooperation, similar than already existing local farmer organisations (cf. annex J; cf. chapter 6.1.4.). Since energy generally is not sufficiently accessible by all the farmers, a pyrolysis unit that might enables farmers to produce bioenergy products, might be a bonus (cf. chapter 6.2.1.2). However this might be contradictable regarding the need to develop a mobile and handy pyrolysis unit, since in such a case the production of bioenergy products might not be possible. In cases of a small-scale implementation this challenge might be important to overcome, since especially energy demand is high and a local energy provider might be highly favourable.

Access to ***market prices*** is highly alterable by external forces and is crucially influencing farm management possibilities and decisions (cf. chapter 6.1.). Since farmers' alteration of market prices is limited to strategies, such as storing their yield in order to receive a better price when the supply is decreasing, they are highly dependent on market trends.

Market prices possibly will not be alterable by an implementation of a biochar system, however it might be important to think about how prices of particularly biochar system products possibly be made affordable for the farmers (E1; cf. annex J).

All three phases of a biochar system influence the income of a farmer, in terms of expenses and earnings (chapter 7.2.). Since ***income*** is crucial in both systems regarding their structure and function, an alteration of the income might profoundly alter the systems resilience and the individual vulnerability (cf. chapter 6.1.3.). Regarding a negative impact on the income, a farmer might be more constraint in his farm management and livelihood decisions and actions than before. If otherwise a farmer might be able to increase his/ her income, by an implementation of a biochar system or by a biochar application to soil, his/ her accessibilities regarding livelihood or farm management assets and strategies might increase. However a farmer who is in the position to dare the risk to implement a biochar system or a biochar application to soil is probably anyway in a better position than other farmers. Consequently this might increase the level of inequity within the village.

As a consequence for an implementation of a biochar system, it is crucial to think about how farmer with lower opportunities or accessibilities might as well profit from an implementation of a biochar system and how the income of a farmer can be secured.

The result of the relative impact of an implementation of a biochar system regarding ***fertilizer, manure*** and ***energy*** was in both villages moderate (cf. chapter 6.2.). However these results have to be understood in their context. Since access to these assets is crucial for farm management decisions, they inevitably are important for the resilience of the system. A biochar system might alter farmers' dependency regarding fertilizer, manure and energy positively, since fertilizer and manure might be partially substituted by biochar (cf. chapter 2.1.). On the other side experimental studies with biochar revealed, that additional fertilizer and manure are in most cases crucial for an increase of the yield (cf. chapter 2.3.). This indicates, that biochar as possible substitute might only slightly alter their dependency on fertilizer and manure. Additional energy production would certainly be a benefit for the farmers, since access to energy is generally limited. But so far biochar pyrolysis units for a small-scale implementation that might generate bioenergy by-products are not yet developed (cf. chapter 2.3.).

> Regarding a biochar implementation it seems to be important to think about how farmers' dependency regarding fertilizer and manure could be mitigated. At the Agricultural University in Bangalore biochar trials with human urine were successfully implemented. In this sense, this might be a possibility to decrease farmers' dependency on fertilizer and manure. However in such a case additional logistical factors should be considered, since the urine has to be collected and the toxic ammonium has to be removed (E4).

7.1.3. Significance of ecological adaption barriers

An implementation of a biochar system is dependent on the initial ***soil-crop-climate system*** (cf. chapter 2.2.). This is strongly determined by the geographic location, not solely between two different communities, such as Chandagalu and Manoor, but as well within the communities. Farmers within a community might produce the same main crops, since climatic conditions are not alterable by the farmers, but their outcome might be different. This is mainly caused by the different soil qualities, which are determined by the different geographic location of the soils (cf. chapter 4). As land is passed on between family members and is limited purchasable on the market, the quality of the soils, and thus the outcome is generally not alterable (cf. chapter 6.1.)

An implementation might alter the soil quality, climate, ***yield*** and ***irrigation system*** of a system. In both cases where soil quality, climate or yield is altered positively or negatively the effect is high on the resilience of the system, since farmers dependencies regarding these assets are high (cf. chapter 6.2.). Since a biochar application might increase the water holding capacity of the soils, water scarcity might be slightly mitigated (cf. chapter 2.1.).

> Before an implementation of a biochar system these specific soil-climate-crop systems within the communities have to be studied in detail regarding their short-term as well as their long-term effect (cf. chapter 2.4.), since likewise soils of a particular climate region might be very heterogeneous regarding their reaction to soil amendments (cf. annex J; chapter 2.3.).

7.2. Significance of village-specific adaption barriers

Chandagalu and Manoor revealed differences regarding their systemic resilience and the vulnerabilities of the individuals within the system. In Manoor soil quality was more dominantly influencing the resilience or the function of the system and as well the individual vulnerabilities, than in Chandagalu. Otherwise in Chandagalu, the irrigation system took a more dominant role in the resilience of the system (cf. chapter 6.2.2.3.)

An analysis of the differences of these two systems showed, that ***soil quality*** is crucial in both villages, but low soil quality in Manoor has a longer cascade of consequences than in Chandagalu (cf. chapter 6.1.4.). This does not imply, that Manoor is more susceptible regarding low soil qualities. In Manoor farmers are mostly more pro-active, in a sense that they show strong interest in new technologies or agricultural products for soil or yield enhancement. This tendency is manifested in their higher interest to take advice by RSK or agricultural extension services or in their higher interest to make use of a biogas plant (cf. chapter 6.1.4.). Another indicator for this tendency is the difference of the derived central asset of the cognitive map, respective socio-ecological system. In Manoor the central asset was farm management, whereas in Chandagalu income derived as main structure- and function-shaping asset within the system. Whereat income received in Manoor the same centrality value than in Chandagalu, farm management strategies overtook strategies for income-generation (cf. chapter 6.1.). In this sense it might be derivable, that farmers in Manoor are more farm management optimizer than farmers in Chandagalu.

> Regarding an implementation of a biochar system, this pro-active tendency might by beneficial. Due to these conditions farmers that might be open to use biochar or a biochar system at a trial basis are easier accessible.

However this result is not without bias. By revising the different type of interview partners, it stands out, that in Manoor at least 9 of 17 interview partners, were farmers that were more risk-takers or more innovative. Consequently these farmers were more active in a sense to seek solutions for an improvement of their soils. This however might be exceptional and is not transferable to the entire village. Furthermore the results of the questionnaire, showed that farmer of Manoor mentioned not particularly more soil enhancement strategies, as farmers in Chandagalu. This questions the validity of this result (cf. chapter 6.2.3.)

In Chandagalu the ***irrigation system*** is more resilient-shaping than in Manoor. This difference might be explainable because at least half of Chandagalu is dependent on artificial irrigation system (E5), whereas Manoor is mostly natural irrigated (cf. chapter 4.2.). Most of the farmers in Chandagalu obtain their water from the canal (cf. chapter 4.1.; 6.1.4.). As a result of a long-time water dispute between the Border States and current canal construction works, the water availability is consequently a sensitive topic for the farmers (cf. chapter 4.1.)

> For an implementation of a biochar system, a biochar application might be certainly favourable for the farmers of Chandagalu, since biochar is3supposed to enhance the water holding capacity of soils (cf. chapter 2.1.) The results of the focus groups were similar, but differentiated. Since there are farmers holding soils with different qualities, there might be differences in demand. The argument of a focus group member “no one will add it to black soils, because they are having more water holding capacity”, points out these differences (cf. annex J). Regarding an implementation of a biochar system or a usage of biochar as soil amendment to increase the water holding capacity, there will probably be different user groups. Accordingly it might be preferable to consider how farmers with soils of good quality might benefit as well by an implementation of a biochar system. For this reason a pyrolysis unit that is constructed to generate bioenergy products as well would be favourable. However such a pyrolysis unit bears the risk of significant land use changes, since the demand of energy is generally high (cf. chapter 2.4.; 6.2.1.2.).

Furthermore Chandagalu and Manoor differs regarding the influence of ***government*** and access to ***trust***. The influence of the government is higher in Manoor than in Chandagalu. However farmers in Manoor were more trustful regarding their local based governmental subdivisions, than farmers in Chandagalu. State-based governmental decisions were criticised in both villages (cf. chapter 6.1.4.). Since biochar system implementation whether large-, or small-scale has to be regulated, especially regarding misuse (cf. chapter 2.2.), it seems to be important, that farmers understand these regulations. This could certainly be achieved by an improvement of the information transfer, as mentioned previously (cf. chapter 7.1.1.) and in the questionnaires (cf. chapter 6.2.3.). In Manoor this information transfer appears to function better than in Chandagalu and therefore farmers are more trustful (cf. chapter 6.1.4.). However this information transfer in Manoor is also tied to certain conditions. Important information sources in Manoor are RSK and local farmer organisations. To have access to these institutions a certain self-initiative is necessary, which might be limited by too high transportation costs or low self-confidence. To be member in local farmer organisations it is furthermore necessary to have interest in helping other people, thus be capable to invest a certain amount of capital (cf. chapter 6.1.4.). However certain farmers might not have enough capital to help other people. As a result they are excluded from these groups and cannot access their help nor information.

> An implementation of a biochar system accordingly has to ensure that possibly all farmers at least have access to information, in order to guaranty that they understand regulations concerning the production and use of biochar.

7.3. Required preconditions for a sustainable implementation

The identification of adaption barriers regarding an implementation of a biochar system indicates that a small-scale implementation within a specific village might be more cost-intensive and less profitable than a large-scale implementation. A small-scale implementation requires social, economic and ecological assets from the farmers, which most of them cannot provide, because their access is limited. Likewise a small-scale implementation might be too risky regarding their strong dependency on soil-crop-climate systems or ensured income and their limited strategies to overcome such potential risks.

A large-scale implementation is basically not that demanding for the individual farmers of the system and potentially more profitable due to economies of scale (cf. chapter 6.2.1.; Baker 2005: 6). Crucial economic assets, such as necessary infrastructure or capital for biochar production phase in such a scenario might be available by sugar factories or rice mills without high influence on the farmers' livelihood. The different scenarios revealed that the only asset, that might be problematic for the biochar production, would be the availability of labours (cf. chapter 6.2.1.). Biomass phase would neither tangent the farmers critically, since farmers cultivate crop such as paddy or sugarcane anyway as food or cash crop and provide it either to sugar factories and rice mills. In this sense bagasse or rice hull husk as biochar feedstock would be available on-site. The most influence on the livelihood of the farmers might be within the application phase. Hereby a farmer decides with respect to his/ her possibilities, whether to use biochar as a soil amendment or not. Regarding potential risks, it might be inevitable to enable guaranties or refunds, in case of application failure, for the farmers.

Accordingly, a large-scale implementation of a biochar system seems to be much easier to realize (cf. annex J). However a large-scale implementation might bear the risk to reinforce existing functions and structures and thus increases the initial dependency of the farmers. A small-scale implementation otherwise has likely the potential to a structural and functional change of the system. According to Gallopin (2006: 299) and Obrist et al. (2011: 283) the resilience of a system is multi-layered and can operate at different scales. A loss of resilience at a "lower", or community-scale, does not consequently result in a loss of resilience at a "higher" or governmental-, institutional-scale. Regarding a small-scale implementation of a biochar system this relationship is important. A transformation of a system requires certain instability, thus a temporary loss of resilience and consequently an endangerment of the individual vulnerabilities (Eakin and Whebe 2009: 365; Gallopìn 2006: 299). In this sense it might be favourable to build reliable institutions on a "higher" scale to ensure a safety net in cases of risks, since the vulnerability of the individuals might be temporarily increased, caused by structural and functional changes of the system at the "lower" scale (Eakin and Wehbe 2009: 355).

The difficulty hereby is to find an appropriate way to lower dependencies and simultaneously increase security. Eakin and Wehbe (2008: 365) suggest doing this through "programs that do not dictate […] but rather facilitate access". This consequently implies for an implementation of a biochar system, that especially access to economic assets that are necessary for an implementation of a small-scale biochar system has to be improved. Likewise it implies that access to relevant social assets, such as reliable institutions have to be improved and made accessible for all farmers. Further it implies that access to ecological assets should not be endangered and in the ideal case improved. The previous outlines in chapter 7.1. and 7.2. revealed at least three superior strategies to overcome these social, economic and ecological adaption barriers for a small-scale implementation of a biochar system:

- Enhancement of trust
- Enhancement of equity
- Enhancement of technology suitability

The results of both villages indicate, that trust regarding new technologies depends primarily on fair rules, information and reliable guaranties. Adger (2009: 345) points out that social limits of adaption often are caused due to different worldviews. Rules regarding production and application of biochar in this sense have to consider "underlying values that are shaping preferences and decisions" (ibid. 2009: 345). Production and application rules therefore may have to be developed within constructive settings with farmers and regulative authorities, so that farmers accept and understand these rules (cf. chapter 7.1.1.).

A soil enhancement by using biochar might need time, since ecological resilience is built on slowly changing variables (cf. chapter 2.3.; annex J; Kasperson et al. 2005: 147). Farmers accordingly have to be informed, not solely about potential benefits but as well about potential consequences. Negative consequences have to be mitigated by reliable guaranties, thus institutional safety nets, that allow to preserve or enhance individual security (Eakin and Whebe 2009: 355).

A small-scale implementation of a biochar system in both villages is difficult, since access to crucial economic assets is lacking (cf. chapter 7.1.2.). Adaption might be facilitated by the enhancement of access to these relevant assets (Smit and Wandel 2006: 287). A possibility to enhance the access to these assets might be by building a local farmer organisation or cooperation. Farmers accordingly could band together and provide necessary assets, such as capital, waste/ feedstock, labour force, etc. and could share the remaining profit (cf. chapter 7.1.2.)

However results of Manoor have shown that certain farmers of the community cannot fulfil the requirements to be an active member of these local farmer organisations or cooperation (cf. chapter 7.2.). Consequently they are excluded from potential benefits. Adger (2006: 277) indicates that attempts to enhance adaptive capacities, thus improve access to assets, often "reduce vulnerability of those best placed to take advantage […], rather than reduce the vulnerability of the marginalized". Fair adaptions are these, which not only increase the adaptive capacities of those that are either way in a better position, but as well "reduce the vulnerability of the most vulnerable" by enhancing their adaptive capacity.

Regarding a biochar system implementation this might be possible by ensuring that as well marginalized farmers, that might not be active members of a farmer organisation, can benefit of an implementation. This might include the production of a product that is affordable also for the most marginalised farmers or by additionally developing mobile and handy biochar pyrolysis units (cf. annex J), which are as well affordable by smallholding farmers or which might be provided by sharing. Providing this access to marginalized farmers is not only important regarding fair adaption programs, it is as well crucial regarding a long-term implementation, since technologies generally "diffuse better if they were offered to the community as a whole rather than to a model farmer or a small selected group" (Baker 2005: 28).

A small-scale biochar implementation should correspond to the needs of the farmers. Since especially labours, manure and energy demand is high (cf. chapter 7.1.2.), the technology as such should provide possibilities to reduce and not reinforce these demands. A biochar system should be less labour-intensive. This might be achievable by implementing mobile and handy biochar pyrolysis units, which allow producing biochar directly on the field. Moreover biochar application should substitute manure application and not reinforce its demand. This might be possible to avoid by using biochar together with treated human urine as fertilizer, instead of manure (cf. E4; chapter 7.1.2.). A bonus would certainly be a development of a small-scale pyrolysis unit, which allows producing bioenergy products. Since such a pyrolysis unit might only generate sufficient energy, if sufficient feedstock is available, such a unit might possibly only be useful for jaggery houses. This implies that generally for Manoor it might be challenging to diversify the utility of a small-scale biochar system.

An enhancement of the technology suitability should furthermore consider the heterogeneity of the biophysical environment, not solely regarding different climate regions, but as well regarding the placed-based heterogeneity. Farmers are holding soils of different quality; therefore the usage of biochar as a soil amendment will not be identical for all the soils (cf. chapter 7.2.). Therefore, place-based trials with different soils should be conducted before an implementation. In this sense, an enhancement of technology suitability should always be place-, respective village-specific. A technology that might function at one place is not unrestricted transferable to another place (Smit and Wandel 2006: 288).

8. Conclusion

The identification of indigenous-knowledge based adaption barriers regarding a sustainable implementation of a biochar system in two agro-climatic different villages in Karnataka, revealed that critical social, economic and ecological assets are limited accessible by the farmers. A large-scale implementation therefore appears to be more cost-efficient and more profitable. However a small-scale implementation might enable a functional and structural positive change on the local scale.

To ensure a sustainable small-scale implementation of biochar the guiding principle - ***decrease dependency and enhance equity*** - should be followed. For a realisation of this principle, access to assets, which are needed for a biochar system, should previously be ensured, in order to prevent an increase of vulnerability of the individuals. This might be possible by applying three measures: i) enhancement of trust; ii) enhancement of equity; and iii) enhancement of technology suitability.

> To enhance trust, rules of production and application of biochar have to be set within a constructive setting of farmers and regulative authorities. Likewise the information transfer regarding new technologies, their benefits and consequences of usage, should be enhanced and a safety net of reliable institutions should be provided in case of failure.
>
> To enhance equity access to economic assets that are crucial for an implementation, such as capital, land rights or feedstock for biochar production should be facilitated. A possibility to realise this facilitation is the building of autonomous local farmers organisations or cooperation. To ensure that all farmers have access to potential benefits resulted by such organisations or cooperation, the prices of biochar and by-products should be affordable also for marginalized farmers.
>
> To enhance technology suitability, a biochar system should diversify farm activities of farmers in a positive manner and not restrict their farm management additionally. In this sense a biochar technology should be low labour-intensive, substitute and not limit manure availability and if possible provide possibilities to generate bioenergy products. Likewise application methods should be defined on a local scale, since climate-soil-crop-systems are locally very heterogeneous.

The study of McGreevy and Shibata (2010) depict interesting insights of a small-scale biochar project in Kameoka city, Japan and illustrates how a biochar project might has to be designed in order to decrease dependency and enhance equity. In Kameoka, a local farmer cooperation initiative was started, where farmers produce biochar and apply it to a conglomerated land of small individual agricultural plots. The cultivated crop, in this case, vegetables, are sold as eco-branded products, since they help to mitigate climate change. An implementation of a biochar system in this sense is in fourfold manner beneficial for the farmers: i) carbon sequestration for which they receive emission-offset credits; ii) soil quality enhancement; iii) improved prices for their agricultural crop; and iv) a creation of “a sense of identification and community” (ibid. 2010: 15).

This example illustrates how an implementation of a small-scale biochar system might be sustainable. However, in order to realise such an implementation, further research is necessary:

Institution availability on a broader scale has to be assessed, in order to answer the following questions:

- Which laws and rules regulate agricultural technology implementations in Karnataka?
- Which institutions for trust building and rules-setting are eligible?
- Which institutions exist, that ensure farmers livelihood in case of a failure?

If a similar biochar project than the illustrated example of Kameoka is implemented within a farming based community in Karnataka, marketing aspects have to be considered, such as:

- How can biochar be added into value within the institutional frame of Karnataka? Or how can the creation of a valuable brand for crop, cultivated with biochar, be achieved?
- How can access to carbon and organic markets be provided?

Regarding the enhancement of technological suitability, further engineering, but also agricultural research is necessary, in order to provide two types of pyrolysis units:

- A mobile and handy pyrolysis unit for villages where availability of feedstock for biochar production is restricted to field-, or home-availability, and in order to reduce labour- and transportation costs.
- A pyrolysis unit for small-scale utilisation, that is able to generate bioenergy products and which might be implementable at jaggery houses or village-based agricultural production businesses.
- Due to the different qualities of soil and farm management accessibilities in every village, soil trials on-site are inevitable before considering an implementation.

A qualitative examination of the suitability of a biochar implementation in these two selected villages, Chandagalu and Manoor, as it was realised in this master thesis project, might be too time-, and cost-intensive for a decision-making in a real implementation context. For this reason, possibly based on the insights of this study, it would be an advantage to develop a standardized technique for an identification of village-specific social, economic and ecological adaption barriers. However this participative study revealed that an incorporation of indigenous knowledge is not only a necessity for sustainable implementations, but is also an enrichment for science in general.

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Annex

Annex A: Interview guideline for expert interviews

Interview guideline for expert interviews

1. Presentation of project

- Biochar implementation (> show scheme of integration into sugarcane production circle)
- Uncertainties (> show scheme of potential uncertainties)
- Importance of involving the needs and vulnerabilities of the local farmers before decision making (> show scheme of project structure)

2. Interview

Topic	Main	In-depth questions	Interests
Agriculture in India	• What is the main function of agriculture in India/ in Karnataka?	• How is it organised? • How many people are working in the first sector/ agriculture? • How many people depend on agriculture?	• Function and value of agriculture of India • Organisational structures
	• What are the social, ecological and economic values of the agriculture of India?	• What are the actual social, ecological and economic problems that agriculture faces in South India?	
Implementation of biochar systems in South India	• What are your interests regarding an implementation of biochar systems in South India?	• What are your expectations? • What are your doubts?	• Opinion about the biochar system implementation project • Advantages/ disadvantages • Important matters to be

			concerned about
	• What do you think about the particular integration of biochar systems into the sugar production circle?		
	• How do you think about the combination of biogas plants with biochar pyrolysis units?		
	• What are the advantages/ disadvantages of the idea of this project?		
	• How do you think the farmers will accept the new technologies?	• How have been your experiences introducing new technologies to farmers? • What type of farmer will accept it?	
	• What could be potential social, ecological and/ or economic dangers/ difficulties?	• Can you compare it to a similar project? • What kind of difficulties did occur?	
Potential research regions	• With your expert knowledge –	• Could you localize these regions	• Potential research regions

2

	where in which region would you implement biochar systems?	on a map? • Whiy did you choose these regions?	
	• How important are physical (soil, climate, water, etc.) factors for the definition regions where biochar could potentially be implemented?		
	• How important are social factors for the definition of regions where biochar could potentially be implemented?		
Financial resources	• How do you think this project could be financed?		• Financial resources
Additional important information	• Do you have anything important to add?		

3

Annex B: Interview guideline for interviews with farmers I

Interview guideline for interviews with farmers Chandagalu/ Manoor

1. Personal profil

Gender:

Age:

Agricultural Education:

# of family members:

Kind of agricultural production:

Size of land (ha):

Soil type:

Caste:

2. Livelihood/ agricultural Production: Focus on rice production and on perceptions of vulnerabilities

Introduction			**Research interests**
• Can you describe us in a few sentences how an ordinary day in your life does look like?			• Understanding of livelihoods • Understanding of sugarcane production circle • Current perceptions of vulnerabilities: • **Exposure**: In what cases
Main research questions	**Ad-hoc questions**	**Specific explanations**	
• Why did you decide to grow this crop?	• Due to climatic/ soil reasons? • Due to economic reasons?	• Where do you buy your seeds? • Where do you sell your yield? • Do you receive a good price for your yield? Why? • Do you have many losses/ expenses? For what?	

• Are you also producing rice?	• Why did you decide to grow rice?	• Where do you sell your yield? Why? • Do you receive a good price for your yield? Why? • Do you have many losses/ expences? For what?	and for how long are they having a feeling of insecurity? • **Sensitivity**: How do/ does they/ the system react on changes? • **Adaptive Capacity/ Strategies:** How do they cope with negative/ positive changes?
• Can you explain me your way of producing/ growing rice plants/ rice?	• Is there a lot of waste? • What are you doing with that waste?	• What kind of waste (rice hull)?	
• How has it been this year: Did you have satisfied growing/ production seasons so far?	• Which one has been your best season so far: Summer (January - March), Kharif (April - September) or this one Rabi (October - December)?	• How many quintals per acre (2.47 = 1 ha)?	
• What is important to receive a good yield (quality and quantity of crops)?	• Soil? • Climate/ Rainfall? • Nonappearance of diseases?		
• What is important to receive a good yield (related to income)?	• Good prices on the market?		
• Have you ever had a bad year/ growing seasons? When?	• What are the reasons for bad years/ growing seasons?	• Does it then affect only you or your entire village?	

• How do you/ the village manage a bad year?	• Do you get help during that time? • Who is helping you?		
• Are you happy to be a farmer?	• What do you like the most? • What do you not like?	• Do you have a second job?	
• Are you happy to live in this village?	• Would you like to live somewhere else being a farmer? Why?		
• How about the others of your community?	• Are they satisfied? • Why not?		
• If you could change something right now: What would it be?	• What would you do different?		
• **Final question**			
• How would your neighbours qualify your household, as rich or poor or in between? • Is there anything important you want me to know about your life as sugarcane producer living in this village?			

3. Biogas: Focus on their experiences with biogas plants and perceptions of vulnerabilities

Introduction			**Research interests**
• Are you using Biogas in your household?			• Understanding of biogas production/ plants and their impact on the community • Current perceptions of vulnerabilities regarding
Main research question	**Ad-Hoc questions**	**Specific explanations**	
• Why are you using it? • Why are you not using it?	• For what are you using it: ○ Cooking? • What are you using instead? • Why?		

• Does everybody in your community use biogas?	• Who not and why?		the implementation and use of biogas plants in their households/ community
• Do you have a biogas plant on your own?	• Do you share one with other people?	• How many people are sharing one biogas plant?	
• How does it work?	• Which waste do you use to make use of the biogas plant? • Are other by-products that are produced during the process?		
• Who did show you the technical aspects?		• NGO? • University? • Company?	
• How did you finance it?	• Have you received any subsidies?		
• Have you ever had any difficulties?	• What kind of difficulties? • When and for how long? • What did you do? • What did the others do? • Did you get help? • Who did help you?		
• How did it change your life/ the life of the community?	• How has it been before?		
• What other technology would	• How do you know about that?		

4

be an improvement for yourself/ your village?			
Final question			
• Is there anything important you want me to know about the use of biogas plants in your village?			

4. Short Input: What is Biochar?

- Use of laminated pictograms/ icons to illustrate the process and the potential benefits.

5. Biochar: Focus on their individual valuation of the project idea (ca. 15')

Input question			**Research interests**
• Which are the benefits of biochar you would enjoy the most and why (use of laminated pictograms/ icons)? What else would you enjoy? ○ Increase of soil quality ○ Increase of yield ○ Use of less fertilizer ○ Good absorber of water ○ Production of energy and decrease of energy costs ○ Use of waste ○ Climate mitigation ○ Receive money for climate mitigation (CDM = Clean Development Mechanism) ○ By-products of pyrolysis: Conversion of biomass to biochar, bio-oil and non-condensable gases			• Potential acceptance/ usefulness for peasant • Current improvement possibilities and indirect perceptions of vulnerabilities • Implementation: Who, where and how?
Main research question	**Ad-Hoc questions**	**Specific Explanations**	
• Would you try to produce	• Why?	• Would you use it to enhance	

biochar?	• Who else would do that and why?	the yield? • Would you rather use it to sell its by-products?	
• Is there anything similar you do know?	• How is it produced? • Who does produce it? Do you produce it? • Are you using it? • How are you using it? • Where do you buy/ sell it?	• How much does it cost? • How much you have to pay?	
• Have you made good experiences using this/ those product/s?	• What has been the biggest benefit?		
• Have there been any difficulties while using this product?	• What kind of difficulties and why?		
• What are your worries using biochar?	• Change of soil (colour, composition)? • Not useful? • No market?		
Final question			
• Is there anything important you want me to know about your opinion of the production and use of biochar?			

Annex C: Interview guideline for interviews with farmers II

Annex D: Profiles of interviewed farmers

Table 1: Personal data of interviewed farmers of Chandagalu

Farmer	Gender	Age	Agricultural education	Family members	Agricultural production	Size of land (ha)	Soil	Caste	Additional information
P1	m	43	n.s.	4	paddy, ragi, sugarcane	2	red, white, black	Vokkaligas	
P2	m	52	visits the meetings and trainings of VC farm	4	sugarcane, paddy, ragi, coconut	7	n.s.	Goudas	
P3	m	67	well-experienced	7	sugarcane, paddy, ragi, bananas, maize, coconut	4	n.s.	Goudas	
P4	w	55	n.s.	6	sugarcane, ragi, paddy, in between crops	1	black	Vokkaligas	
P5	m	42	parents	9	sugarcane; Jaggery house owner	10	black, red	n.s.	cultivates the land of his uncle
P6	m	65	ancient knowledge	5	paddy, sugarcane, banana, coconut	10.5	black, red	Vokkaligas	
P7	w	66	n.s.	4	paddy, livestock (cows and hennes)	3	black, red	Vokkaligas	
P8	w/ m	42/ 23	n.s.	3	sugarcane, paddy	1.5	black	Goudas	
P9	w/ m	46/ 38	parents, husband	2/ 4	sugarcane, paddy/ sugarcane/ paddy	2/ 1.5	black/ black	Vokkaligas/ Vokkaligas	neighbours, are farming together
P10	m	27	n.s.	6	paddy, sugarcane, ragi	3.5	black, red	Vokkaligas	
P11	m	34	since young age	4	sugarcane, paddy, ragi	10	red	Goudas	
P12	m	32	started farming at age 10	5	paddy, sugarcane, ragi	4	red	Vokkaligas	
P13	m/m	28/ 22	parents/ parents	5/ 6	paddy, sugarcane, ragi/ paddy, sugarcane, ragi	0.5/ 5	red/ red	Vokkaligas/ Vokkaligas	
P14	m/ m	24/ 65	n.s.	5	paddy, sugarcane, ragi	3.5	black	Vokkaligas	
P15	m	69	parents	9	paddy, sugarcane	2	red, black	Vokkaligas	
P16	m	53	VC farm and parents	5	paddy, sugarcane	2.5	brownish	Vokkaligas	
P17	m	36	n.s.	15	paddy, sugarcane, ragi, Jaggery house owner	5.5	red, black	Vokkaligas	
P18	m	52	since young age	3	paddy, sugarcane	2	black, red	Goudas	
P19	w	45	parents, husband and brother	4	paddy	1	black, brown	Vokkaligas	
P20	w	48	n.s.	2	ragi, paddy, sugarcane, mulberry	4	yellow/ white, black	Vokkaligas	

Table 2: Personal data of interviewed farmers of Manoor

Farmer	Gender	Age	Agricultural education	Family members	Agricultural production	Size of land (ha)	Soil	Caste	Additional information
P21	m	45	training camps	6	paddy, groundnut, vegetables, green graham, pulses	1	sandy soil	Mogavira	
P22	m	56	parents, uncle	40	paddy, groundnut	4.5	sandy soil	Bilawa	
P23	m	51	training in farming in Bangalore, parents	5	paddy, groundnut, vegetables, pulses	3	sandy soil	Bunts	
P24	w	59	parents	6	paddy, groundnut, vegetables, pules	2.5	sandy soil	Brahamins	
P25	m	62	parents	8	paddy, groundnut	5	sandy soil	Bunts	
P26	w/ m	64/ 38	parents	6	paddy, pulses	5	sandy soil, but more gravels	Bunts	
P27	m	68	parents	5	paddy, pulses, groundnuts	2	n.s.	Bunts	
P28	m	72	n.s.	5	before paddy, pulses, groundnuts; now: coconuts and arecanut	3.65	sandy soil	Brahamins	
P29	m	47	father	5	paddy, groundnut, coconut	3.5	sandy soil	Brahamins	
P30	w	54	by her own	2	is labouring for 1000 per month; cow	0.30	n.s.	n.s.	
P31	w	33	n.s.	9	paddy, pulses, groundnut	0.60	coarse soil	Bunts	
P32	m	77	since young age	5	coconut, arecanut, pulses, vegetables, paddy	5	black soil but sandy	Brahamins	
P33	w	35	parents	8	paddy, groundnuts, pulses	3	sandy red soil	Pujari	
P34	w	39	parents	5	paddy, pulses, groundnut	1.5	red soil	Bilawa/ Pujari	
P35	w	60	n.s.	7	paddy, groundnut	1	black sandy soil	Pujari	
P36	m	51	parents	4	paddy; pulses; groundnut	3 (plus 2 on lease)	red sandy soil	Bunts	
P37	m	66	parents	6	paddy, groundnut	4	red sandy soil	Mogavira	

Annex E: Standardized questionnaire

QUESTIONNAIRE **CHANDAGALU/ MANOOR NOVEMBER 2013**

1. Introduction

Dear farmer

In February 2012 the Interdisciplinary Platform „InnoPool“ of the University of Zurich launched a project in which an implementation of a new agricultural technique in Karnataka is considered. Before implementation of new technologies it is important to understand the potential stakeholders and users. For this reason I am conducting a short questionnaire to explore your individual needs and vulnerabilities. I am a M. Sc. Student of Geography and Agricultural Economics of the University of Zurich, Switzerland and this is a part of my master thesis. All information will be treated anonymously and is only used for this particular project.

Thank you cordially for your cooperation!

2. Profile (Please use capital letters!)

Gender	
Age	
Caste	
Academic Education	
Agricultural Education	
Number of family members	
Number of labourers	
Kind of agricultural production	
Size of land (acre)	
Soil type	
Travel time to land/ farm	
Gross income per year	
Net income per year	

4. Questions

This section contains 8 questions regarding your livelihood as a farmer. Each question contains 4 parts. In the first part you have to decide how strong a given impact does influence your livelihood if you are not able to make a lot of profit. Try to weight the magnitude of the influence by giving the following weights: 0 = none, 1 = less, 2 = medium, 3 = a lot, 4 = huge. In the second part of the same impact is given, but this time you are able to make profit. Try also to weight the magnitude of the influence by giving the weights. In the third part of the question you have to think about what is the main reason for the impact. The fourth and last part is about how you manage such an impact.

1 a) Weight the impact of the following situation on your livelihood:

Not a lot of profit is possible to make and you are not having a good yield.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

1 b) Weight the impact of the following situation on your livelihood:

Profit is possible to make and you are not having a good yield.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

1

University of Zurich[UZH]

1 c) What is the main reason for a decrease of the yield in your land?

____
____
____

1 d) How do you manage usually a decrease of the yield?

____
____
____

2 a) Weight the impact of the following situation on your livelihood:

Not a lot of profit is possible to make and the youngsters move to the city.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

2 b) Weight the impact of the following situation on your livelihood:

Profit is possible to make and the youngsters move to the city.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

2 c) What is the main reason that the youngsters are moving to the city?

____
____
____

2 d) How do you manage the situation that the youngsters are leaving the village?

____
____
____

3 a) Weight the impact of the following situation on your livelihood:

Not a lot of profit is possible to make and there is a labourer problem.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

3 b) Weight the impact of the following situation on your livelihood:

Profit is possible to make and there is a labourer problem.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

3 c) What is the main reason of the labourer problem?

____
____
____

3 d) How do you usually manage a labourer problem?

____
____
____

2

University of Zurich[UZH]

4 a) Weight the impact of the following situation on your livelihood:

Not a lot of profit is possible to make and you are having a lot of health costs.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

4 b) Weight the impact of the following situation on your livelihood:

Profit is possible to make and you are having a lot of health costs.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

4 c) What is the main reason of issues with the health costs?

____
____
____

4 d) How do you manage usually the situation of facing health costs?

____
____
____

5 a) Weight the impact of the following situation on your livelihood:

Not a lot of profit is possible to make and the government made a scheme regarding financial help. But this governmental scheme does not help you, only a few people in the village.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

5 b) Weight the impact of the following situation on your livelihood:

Profit is possible to make and the government made a scheme regarding financial help. But this governmental scheme does not help you, only a few people in the village.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

5 c) What is the main reason of unfair governmental schemes?

____
____
____

5 d) How do you manage usually if the government has implemented an unfair scheme?

____
____
____

6 a) Weight the impact of the following situation on your livelihood:

Not a lot of profit is possible to make and your soil gets spoiled.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

3

University of Zurich[UZH]

6 b) Weight the impact of the following situation on your livelihood:

Profit is possible to make and your soil gets spoiled.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

6 c) What is the main reason why your soil gets spoilt?

____
____
____

6 d) How do you manage the situation that your soil gets spoilt?

____
____
____

7 a) Weight the impact of the following situation on your livelihood:

Not a lot of profit is possible to make and the costs of fertilizer and manure are increasing.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

7 b) Weight the impact of the following situation on your livelihood:

Profit is possible to make and the costs of fertilizer and manure are increasing.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

7 c) What is the main reason in your opinion that the prices of manure and fertilizer are increasing?

____
____
____

7 d) How do you usually manage an increase of price of fertilizer and manure?

____
____
____

8 a) Weight the impact of the following situation on your livelihood:

Not a lot of profit is possible to make and a new technology has been implemented. But the technology doesn't help you, because it seems that it is not fully developed to the needs of your usage.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

8 b) Weight the impact of the following situation on your livelihood:

Profit is possible to make and a new technology has been implemented. But the technology doesn't help you, because it seems that it is not fully developed to the needs of your usage.

☐ 0 = none ☐ 1 = less ☐ 2 = medium ☐ 3 = a lot ☐ 4 = huge

University of Zurich[UZH]

8 c) What is the main reason of a failure of new technologies?

____
____
____

8 d) How do you manage usually a failure of a new technology?

____
____
____

ಪ್ರಶ್ನಾವಳಿಗಳ   ಉಡುಪಿ, ಡಿಸೆಂಬರ್ 2013

1. ಪರಿಚಯದ

ಮಾನ್ಯ ರೈತರೆ

ಫೆಬ್ರವರಿ 2012 ರಲ್ಲಿ ಅಂತಶ್ಯಾಸ್ತ್ರೀಯ ವೇದಿಕೆ "InnoPool" ಜ್ಯೂರಿಚ್ ವಿಶ್ವವಿದ್ಯಾಲಯ ಅವರ ಒಟ್ಟಿಗೆ ಕೃಷಿ ವಿಜ್ಞಾನ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಬೆಂಗಳೂರು, ಒಂದು ಹೊಸ ಕೃಷಿ ತಂತ್ರ ಯೋಜನೆಯ ಅಳವಡಿಕೆಯ ಬಿಡುಗಡೆ ಪರಿಗನಣಿಸಲಾಗುತಿದೆ. ಈ ಹೊಸ ತಂತ್ರಜ್ಞಾನಗಳನ್ನು ಅನುಷ್ಠಾನಕ್ಕೆ ಮೊದಲು ಇದರ ಮುಖ್ಯ ಬಳಕೆದಾರರನ್ನು ಮತ್ತು ವಿಭವವು ಮಧ್ಯಸ್ಥಗಾರರನ್ನು ಅರ್ಥಮಾಡಿಕೊಳ್ಳುವುದು ಮುಖ್ಯ. ಈ ಕಾರಣಕ್ಕಾಗಿ ನಿಮ್ಮ ವೈಯಕ್ತಿಕ ಅಗತ್ಯ ಮತ್ತು ಅಪಾಯ ಸಾಧ್ಯತೆಯನ್ನು ಪರಿಶೋಧಿಸಲು ಒಂದು ಚಿಕ್ಕ ಪ್ರಶ್ನಾವಳಿ ನಾನು ನಡೆಸುವುದು. ನಾನು ಭೂಗೋಳ ಮತ್ತು ಕೃಷಿ ಅರ್ಥಶಾಸ್ತ್ರ ಎಂ ಎಸ್ಸಿ ವಿದ್ಯಾರ್ಥಿ ಮತ್ತು ಈ ನನ್ನ ಮಾಸ್ಟರ್ ಪ್ರಬಂಧ ಜ್ಯೂರಿಚ್, ಸ್ವಿಜರ್ಲ್ಯಾಂಡ್ ವಿಶ್ವವಿದ್ಯಾಲಯ ಮಂಡಿಸಿದ ಒಂದು ಭಾಗವಾಗಿದೆ. ಎಲ್ಲಾ ಮಾಹಿತಿ ಅನಾಮಧೇಯವಾಗಿ ಈ ನಿರ್ದಿಷ್ಟ ಯೋಜನೆಗೆ ಮಾತ್ರ ಬಳಸಲಾಗುತ್ತದೆ.

ನಿಮ್ಮ ಸಹಕಾರಕ್ಕಾಗಿ ಸೌಜನ್ಯಯುತವಾಗಿ ಧನ್ಯವಾದಗಳು!

2. ಕಿರು ಪರಿಚಯ (ದೊಡ್ಡ ಅಕ್ಷರಗಳನ್ನು ಬಳಸಿ!)

ಲಿಂಗ	
ವಯಸ್ಸು	
ಜಾತಿ	
ಶಿಕ್ಷಣ	
ಕೃಷಿ ಶಿಕ್ಷಣ	
ಕುಟುಂಬ ಸದಸ್ಯರ ಸಂಖ್ಯೆ	
ಕಾರ್ಮಿಕರ ಸಂಖ್ಯೆಯೆ	
ಬಗೆಯ ಕೃಷಿ ಉತ್ಪಾದನೆ	
ಭೂಮಿ ಗಾತ್ರ (ಎಕರೆ)	
ಮಣ್ಣಿನ ವಿಧ	
ನಿತ್ಯ ಕೃಷಿ ಭೂಮಿಗೆ ಹೋಗಿ ಬರುವದಕ್ಕೆ ಬೇಕಾದ ಸಮಯ	
ವರ್ಷಕ್ಕೆ ನಿವ್ವಳ ಆದಾಯ	
ವಾರ್ಷಿಕ ಲಾಭ	

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3. ಪ್ರಶ್ನೆಗಳು

ಈ ವಿಭಾಗವು, ರೈತರೆ ನಿಮ್ಮ ಜೀವನಾಧಾರದಬಗ್ಗೆ 8 ಪ್ರಶ್ನೆಗಳೊಂದಿದೆ. ಪ್ರತಿ ಪ್ರಶ್ನೆ 4 ಭಾಗಗಳನ್ನು ಹೊಂದಿದೆ. ಮೊದಲ ಭಾಗದಲ್ಲಿ, ಒಂದು ವೇಳೆ ನೀವು ಬಹಳಷ್ಟು ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯವಿಲ್ಲದ್ದಾಗ, ಎಷ್ಟು ಪ್ರಬಲ ನಿರ್ದಿಷ್ಟ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದ ವೇಳೆಯಂದು ನಿರ್ಧರಿಸುತೆ. ಕೆಳಗಿನ ತೂಕ ನೀಡುವ ಮೂಲಕ ಪ್ರಭಾವದ ಪ್ರಮಾಣವನ್ನು ನೀಡಲು ಪ್ರಯತ್ನಿಸಿ: 0 = ಯಾವುದೂ ಇಲ್ಲ 1 = ಕಡಿಮೆ 2 = ಮಧ್ಯಮ 3 ಬಹಳಷ್ಟು 4 = ಭಾರಿ. ಎರಡನೇ ಭಾಗದಲ್ಲಿ ಅದೇ ಪರಿಣಾಮ ನೀಡಲಾಗುತ್ತದೆ, ಆದರೆ ಈ ಬಾರಿ ನೀವು ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯವಾಗುತ್ತದೆ. ಕೆಳಗಿನ ತೂಕ ನೀಡುವ ಮೂಲಕ ಪ್ರಭಾವದ ಪ್ರಮಾಣವನ್ನು ನೀಡಲು ಪ್ರಯತ್ನಿಸಿ. ಪ್ರಶ್ನೆಯ ಮೂರನೇ ಭಾಗದಲ್ಲಿ ನಿಮ್ಮ ಯೋಚನೆಗೆ ಮುಖ್ಯ ಕಾರಣದ ಪ್ರಭಾವ ಏನು. ನಾಲ್ಕನೇ ಭಾಗ, ನೀವು ಹೇಗೆ ಇಂತಹ ಪ್ರಭಾವವನ್ನು ನಿರ್ವಹಿಸಬಹುದು.

1 a) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಬಹಳಷ್ಟು ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯವಿಲ್ಲ ಮತ್ತು ನೀವು ಉತ್ತಮ ಇಳುವರಿ ಹೊಂದಿಲ್ಲ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

1 b) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯ ಮತ್ತು ನೀವು ಉತ್ತಮ ಇಳುವರಿ ಹೊಂದಿಲ್ಲ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

1 c) ನಿಮ್ಮ ಭೂಮಿ ಇಳುವರಿ ಕಡಿಮೆಯಾಗಲು ಮುಖ್ಯ ಕಾರಣಗಳೇನು?

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1 d) ಇಳುವರಿ ಕಡಿಮೆಯಾಗಿದಾಗ ಸಾಮಾನ್ಯವಾಗಿ ನೀವು ಹೇಗೆ ನಿರ್ವಹಿಸಬಹುದು?

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2 a) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಬಹಳಷ್ಟು ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯವಿಲ್ಲ ಮತ್ತು ಯುವಜನರು ಸಿಟಿ ತೆರಳುತಿದ್ದರೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

2 b) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯ ಮತ್ತು ಯುವಜನರು ಸಿಟಿ ತೆರಳುತಿದ್ದರೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

2 c) ಯುವಕರು ನಗರಕ್ಕೆ ಚಲಿಸುವ ಒಂದು ಮುಖ್ಯ ಕಾರಣ ಏನು?

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2 d) ಹೇಗೆ ನೀವು ಯುವಕರು ಗ್ರಾಮ ಬಿಟ್ಟು ಹೋಗುವ ಪರಿಸ್ಥಿತಿಯನ್ನು ನಿರ್ವಹಿಸುತಿದಿರ?

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3 a) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಬಹಳಷ್ಟು ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯವಿಲ್ಲ ಮತ್ತು ದುಡಿಮೆಗಾರ ಸಮಸ್ಯೆಇದೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

3 b) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯ ಮತ್ತು ದುಡಿಮೆಗಾರ ಸಮಸ್ಯೆಇದೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

3 c) ದುಡಿಮೆಗಾರರ ಸಮಸ್ಯೆಗೆ ಮುಖ್ಯ ಕಾರಣಗಳಏನು?

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3 d) ಸಾಮಾನ್ಯವಾಗಿ ನೀವು ಹೇಗೆ ದುಡಿಮೆಗಾರರ ಸಮಸ್ಯೆ ನಿರ್ವಹಿಸಬಹುದು?

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4 a) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಬಹಳಷ್ಟು ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯವಿಲ್ಲ ಮತ್ತು ನಿಮಗೆ ಬಹಳಷ್ಟು ಆರೋಗ್ಯ ವೆಚ್ಚ ಉಂಟಾಗಿದೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

4 b) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯ ಮತ್ತು ನಿಮಗೆ ಬಹಳಷ್ಟು ಆರೋಗ್ಯ ವೆಚ್ಚ ಉಂಟಾಗಿದೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

4 c) ಚಿಕಿತ್ಸಾವೆಚ್ಚಗಳ ಸಮಸ್ಯೆಗೆ ಮುಖ್ಯ ಕಾರಣವೇನು?

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4 d) ನೀವು ಆರೋಗ್ಯ ವೆಚ್ಚಗಳನ್ನು ಎದುರಿಸುತ್ತಿರುವ ಪರಿಸ್ಥಿತಿ ಸಾಮಾನ್ಯವಾಗಿ ಹೇಗೆ ನಿರ್ವಹಿಸ್ತೀರಿ?

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5 a) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಬಹಳಷ್ಟು ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯವಿಲ್ಲ ಮತ್ತು ಸರ್ಕಾರ, ಆರ್ಥಿಕ ಸಹಾಯದಬಗ್ಗೆ ಒಂದು ಯೋಜನೆ ಮಾಡಿದೆ. ಆದರೆ ಈ ಸರ್ಕಾರಿ ಯೋಜನೆ ನಿಮಗೆ ಸಹಾಯ ಮಾಡುವುದಿಲ್ಲ, ಗ್ರಾಮದ ಕೆಲವು ಜನರಿಗೆ ಮಾತ್ರ ಸಹಾಯವಾಗಿದೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

5 b) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯ ಮತ್ತು ಸರ್ಕಾರ, ಆರ್ಥಿಕ ಸಹಾಯದಬಗ್ಗೆ ಒಂದು ಯೋಜನೆ ಮಾಡಿದೆ. ಆದರೆ ಈ ಸರ್ಕಾರಿ ಯೋಜನೆ ನಿಮಗೆ ಸಹಾಯ ಮಾಡುವುದಿಲ್ಲ, ಗ್ರಾಮದ ಕೆಲವು ಜನರಿಗೆ ಮಾತ್ರ ಸಹಾಯವಾಗಿದೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

5 c) ಸರ್ಕಾರಿ ಯೋಜನೆಗಳು ಅನ್ಯಾಯವಾಗಲು ಮುಖ್ಯ ಕಾರಣ ಏನು?

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5 d) ಸರ್ಕಾರದ ಅನ್ಯಾಯದ ಅನುಷ್ಠಾನ ಯೋಜನೆ ಬಂದಮೇಲೆ ಸಾಮಾನ್ಯವಾಗಿ ನೀವು ಹೇಗೆ ನಿರ್ವಹಿಸುತೀರ?

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6 a) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಬಹಳಷ್ಟು ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯವಿಲ್ಲ ಮತ್ತು ನಿಮ್ಮ ಮಣ್ಣು ಸುಲುಕೊಂಡಿದೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

6 b) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯ ಮತ್ತು ನಿಮ್ಮ ಮಣ್ಣು ಸುಲುಕೊಂಡಿದೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

6 c) ನಿಮ್ಮ ಮಣ್ಣು ಹಾಳಾಗಿ ಸಿಲುಕೊಳಲು ಮುಖ್ಯ ಕಾರಣ ಏನು?

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6 d) ನಿಮ್ಮ ಮಣ್ಣು ಸುಲುಕೊಂಡು ಬಂದರೆ ನೀವು ಹೇಗೆ ನಿರ್ವಹಿಸಬಹುದು?

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7 a) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಬಹಳಷ್ಟು ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯವಿಲ್ಲ ಮತ್ತು ರಸಗೊಬ್ಬರ ಮತ್ತು ಗೊಬ್ಬರ ವೆಚ್ಚ ಹೆಚ್ಚಾಗುತ್ತಿದೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

7 b) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯ ಮತ್ತು ರಸಗೊಬ್ಬರ ಮತ್ತು ಗೊಬ್ಬರ ವೆಚ್ಚ ಹೆಚ್ಚಾಗುತ್ತಿದೆ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

7 c) ನಿಮ್ಮ ಅಭಿಪ್ರಾಯದಲ್ಲಿ ಗೊಬ್ಬರ ಮತ್ತು ರಸಗೊಬ್ಬರ ಬೆಲೆ ಹೆಚ್ಚಾಗುತ್ತಿರಲು ಮುಖ್ಯ ಕಾರಣ ಏನು?

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7 d) ನೀವು ಸಾಮಾನ್ಯವಾಗಿ ಹೇಗೆ ರಸಗೊಬ್ಬರ ಮತ್ತು ಗೊಬ್ಬರ ವೆಚ್ಚ ಏರಿಕೆ ನಿರ್ವಹಿಸುತ್ತೀರ?

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____

____

8 a) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಬಹಳಷ್ಟು ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯವಿಲ್ಲ ಮತ್ತು ಹೊಸ ತಂತ್ರಜ್ಞಾನ ಅಳವಡಿಸಲಾಗಿದೆ. ಆದರೆ ಈ ತಂತ್ರಜ್ಞಾನ ನಿಮಗೆ ಸಹಾಯ ಮಾಡುವುದಿಲ್ಲ, ಯಾಕಂದರೆ ಸಂಪೂರ್ಣವಾಗಿ ನಿಮ್ಮ ಅಭಿವೃದ್ಧಿ ಬಳಕೆಯ ಅಗತ್ಯಗಳನ್ನು ತಿಳುದುಕೊಂಡ್ದಿಲ್ಲ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

8 b) ಕೆಳಗಿನ ಪರಿಸ್ಥಿತಿಯ ಪರಿಣಾಮ ನಿಮ್ಮ ಜೀವನಾಧಾರದಮೇಲೆ ಏನು:

ಲಾಭ ಮಾಡಲು ಸಾಧ್ಯ ಮತ್ತು ಹೊಸ ತಂತ್ರಜ್ಞಾನ ಅಳವಡಿಸಲಾಗಿದೆ. ಆದರೆ ಈ ತಂತ್ರಜ್ಞಾನ ನಿಮಗೆ ಸಹಾಯ ಮಾಡುವುದಿಲ್ಲ, ಯಾಕಂದರೆ ಸಂಪೂರ್ಣವಾಗಿ ನಿಮ್ಮ ಅಭಿವೃದ್ಧಿ ಬಳಕೆಯ ಅಗತ್ಯಗಳನ್ನು ತಿಳುದುಕೊಂಡ್ದಿಲ್ಲ.

☐ 0 = ಯಾವುದೂ ಇಲ್ಲ ☐ 1 = ಕಡಿಮೆ ☐ 2 = ಮಧ್ಯಮ ☐ 3 ಬಹಳಷ್ಟು ☐ 4 = ಭಾರಿ

8 c) ಹೊಸ ತಂತ್ರಜ್ಞಾನಗಳ ವಿಫಲತೆಗೆ ಮುಖ್ಯ ಕಾರಣ ಏನು?

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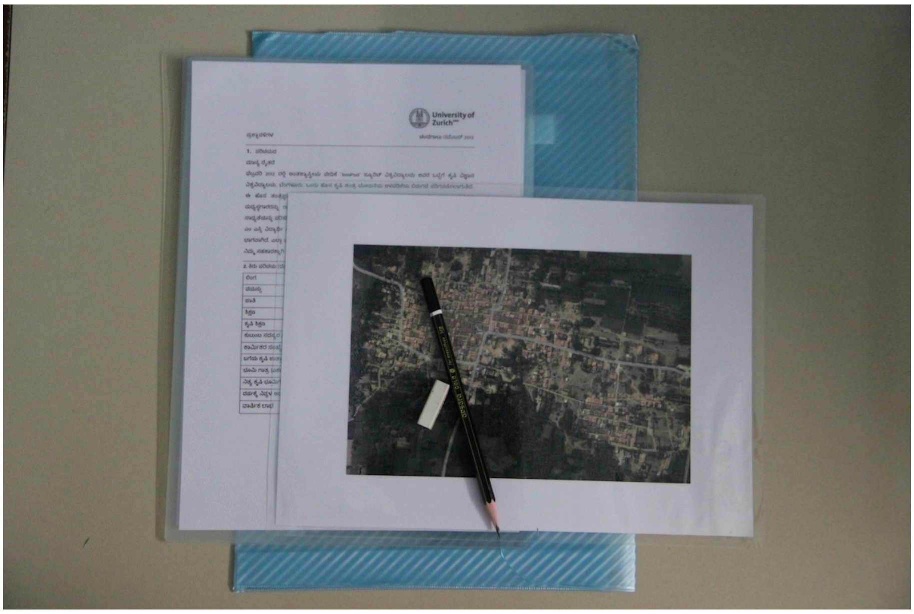
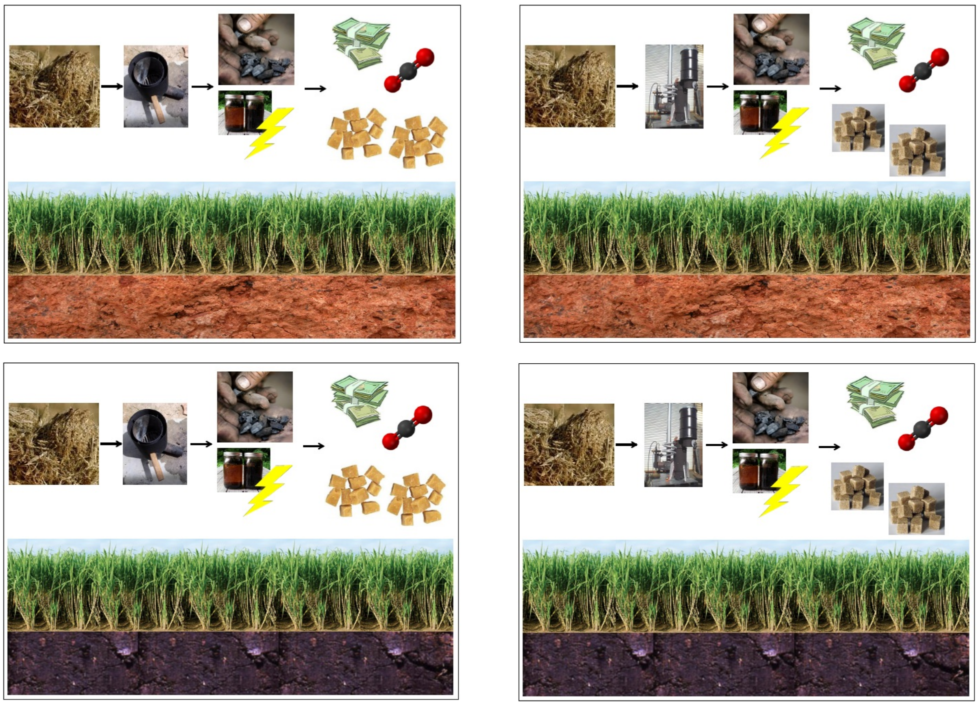
University of Zurich[UZH]

8 d) ಸಾಮಾನ್ಯವಾಗಿ, ನೀವು ಹೊಸ ತಂತ್ರಜ್ಞಾನ ವೈಫಲ್ಯ ತೆಯನು ನಿರ್ವಹಿಸುವುದು ಹೇಗೆ?

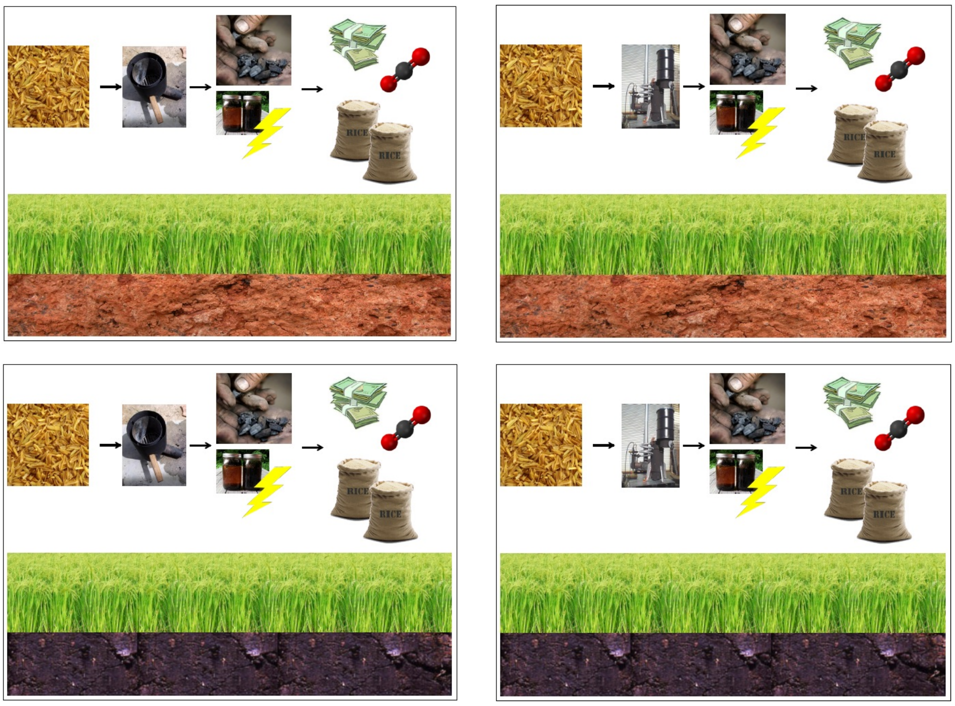

University of Zurich

Annex F: Focus group with students

Scenarios Chandagalu (dry, sugarcane, small- and large-scale, good/low quality soil)



Scenarios Mandya (wet, paddy, small- and large-scale, good/ low quality soil)



Annex G: Focus group with farmers

TRADE-OFF GAME CHANDAGALU/ MANOOR NOVEMBER/ DEZEMBER 2013

- **Round 1: Every player has got some basic conditions:**
  - Red or black soil
  - Crop (paddy, sugarcane, pulses, groundnut, others)
  - Irrigated land (well, drip-irrigation)/ non-irrigated land (rain)
  - Family members (<5, 5-10, >10)
  - Savings (5000, 10 000, 20 000)

  Every player can chose between three possibilities (red, blue, yellow)
  - Possibility to get a loan (6000, but 1500 has to be paid back every year)
  - Possibility to invest in biochar (technology is proven, high yield is proven, part of it gets subsidised, bargasse is given → high starting investment, but costs are decreasing in the following year)
    - Possibility 1: Investment only one person (6000) and all benefits for the same person (4000)
    - Possibility 2: Investment 4 people together (1500), but benefits are shared also (1000)

- **Round 2-4: Basic conditions change for everybody (Cards A):**
  - Price of yield increases (+2000)
  - Price of yield decreases (-2000)

  Distribution of initial savings (the same than year 1) plus or minus 2000 and in case of investment the also get the benefit, but in case of a loan, they have to pay back 1500

  Conditions change individually (Cards B):
  - Bad yield
  - Youngsters are moving to the city and you need a labourer
  - High wages for labourers
  - Illness
  - Fertilizer costs are increasing
  - Good yield
  - Governmental scheme
  - Everything stays the same
  - Soil gets spoilt

  Again every player can chose between the three possibilities:
  - Possibility to get a loan (6000, but 1500 has to be paid back every year)
  - Possibility to invest in biochar:
    - Possibility 1 a: Investment only one person (6000) and all benefits for the same person (4000)
    - Possibility 1b: 2nd investment only one person (2000) and all benefits for the same person (4000)
    - Possibility 2 a: Investment 4 people together (1500), but benefits are shared also (1000)
    - Possibility 2 b: 2nd investment 4 people together (500), but benefits are shared also (1000)

Annex H: Biochar system variables for cognitive map

Table 1: Relevant components of a large-scale biochar system during biomass phase and their impacts and influences on assets of farming based livelihoods (own representation).

Biomass phase		
Variables	**Impacts**	**Influenced by**
Feedstock production	Farm management Laborers Income	Farm management Climate/ Soil quality/ Sugarcane, respectively paddy Capital/ savings Market/ Market price Land rights Laborers Waste
Feedstock preparation	Laborers	Laborers
Feedstock storage	Laborers	Laborers
Feedstock transportation	Laborers	Transportation Land (size/ fragmentation) Laborers

Table 2: Relevant variables of a large-scale biochar system during conversion phase and their impacts and influences on farming based livelihoods (own represention)

Conversion phase		
Variables	**Impacts**	**Influenced by**
Biochar production by pyrolyis	Laborers	Labourers Trust
Production by co-products (bio-oil, syngas)	Energy	Energy Market
Biochar preparation	Laborers	Laborers
Biochar storage	Laborers	Laborers

Table 3: Relevant variables of a large-scale biochar system during application phase and their impacts and influences on farming based livelihoods (own representation).

Application phase		
Variables	**Impacts**	**Influenced by**
Biochar distribution	Income	Farm management Capital/ savings Market/ Market prices Trust Mobility
Biochar transportation	Income	Land (size/ fragmentation) Transportation Capital/ savings Farm management
Biochar application	Farm management Fertilzer Manure Income Laborers Soil quality/ Climate Government Yield Irrigation system	Land (flat land/ geographic location of the land) Farm management Laborers Soil quality/ Climate Scientists Government Capital/ savings

Table 4: Relevant components of a small-scale biochar system during biomass phase and their impacts and influences on assets of farming based livelihoods (own representation).

Biomass phase		
Variables	**Impacts**	**Influenced by**
Feedstock production	Farm management Laborers Income	Farm management Climate/ Soil quality/ Sugarcane, respectively Paddy Capital/ savings Market/ Market price Land rights Laborers Waste
Feedstock preparation	Farm management Laborers Income	Capital/ savings Farm management Laborers
Feedstock storage	Farm management Laborers Income	Capital/ savings Farm management Laborers
Feedstock transportation	Farm management Income	Capital/ savings Farm management Land (size/ fragmentation) Transportation

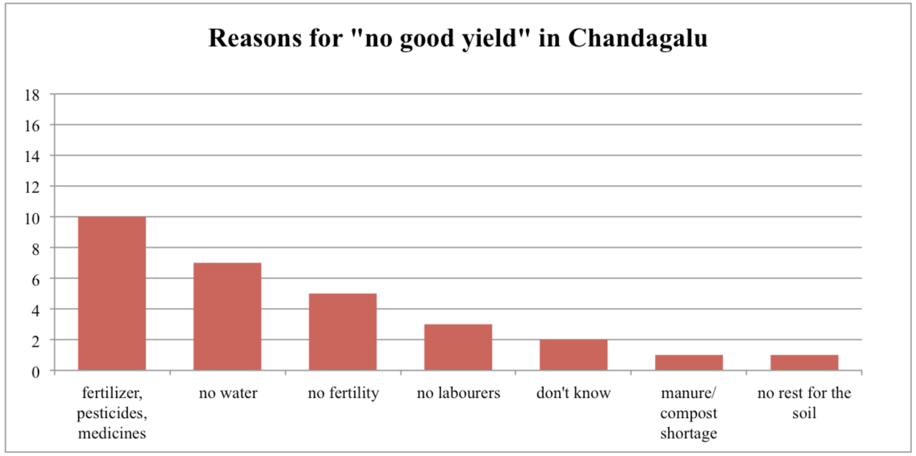
Table 5: Relevant variables of a small-scale biochar system during conversion phase and their impacts and influences on farming based livelihoods (own represention)

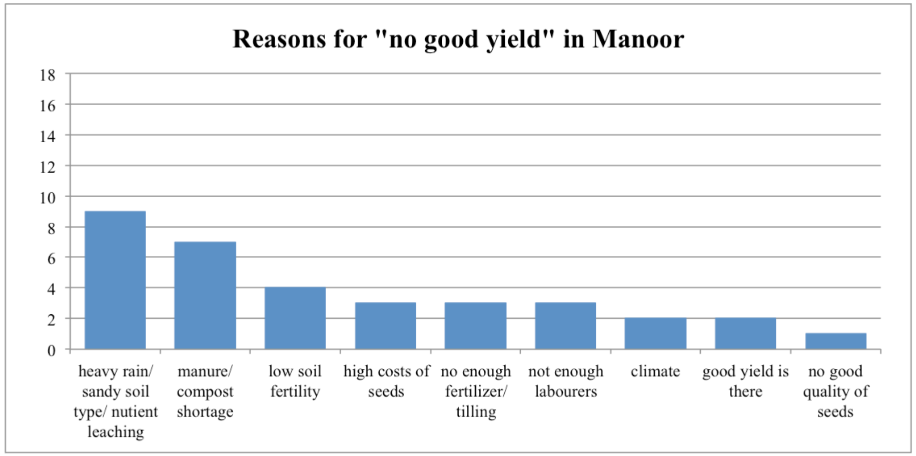
Conversion phase		
Variables	**Impacts**	**Influenced by**
Biochar production by pyrolyis	Income Laborers Government Farm management	Farm management Capital/ savings Land rights Labourers Trust Government Scientists
Production by co-products (bio-oil, syngas)	Energy Income Government	Energy Market Government Scientists
Biochar preparation	Laborers Farm management Income	Capital/ savings Laborers Farm management
Biochar storage	Laborers Farm management Income	Capital/ savings Laborers Farm management

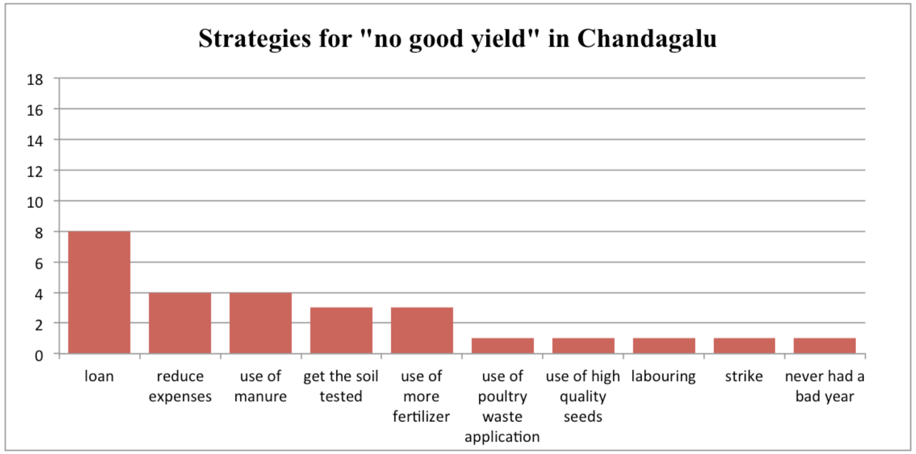
Table 6: Relevant variables of a small-scale biochar system during application phase and their impacts and influences on farming based livelihoods (own representation).

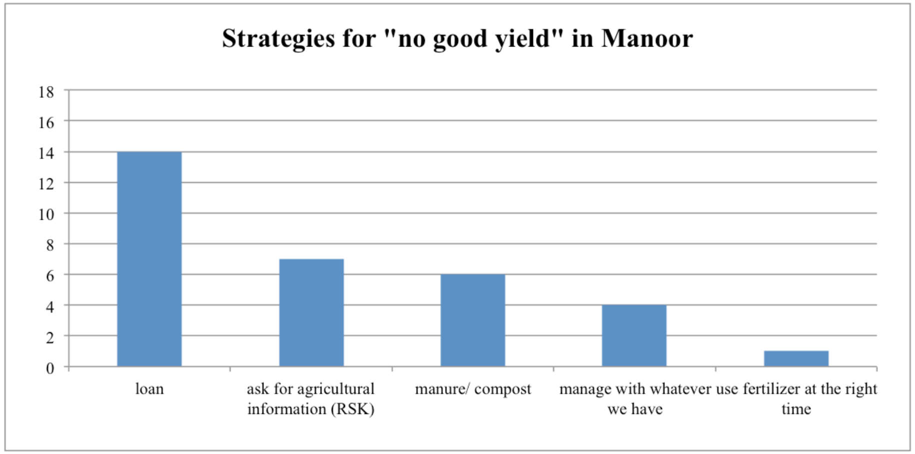
Application phase		
Variables	**Impacts**	**Influenced by**
Biochar distribution	Income	Farm management Capital/ savings Market/ Market prices Trust Mobility
Biochar transportation	Income	Land (size/ fragmentation) Transportation Capital/ savings Farm management
Biochar application	Farm management Fertilizer Manure Income Laborers Soil quality/ Climate Government Yield Irrigation system	Land (flat land/ geographic location of the land) Farm management Laborers Soil quality/ Climate Scientists Government Capital/ savings

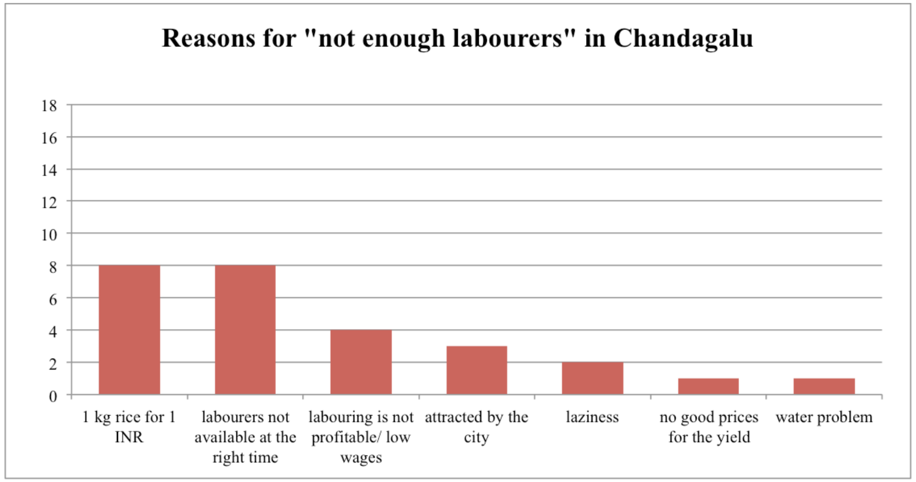
Annex I: Results of standardized questionnaire

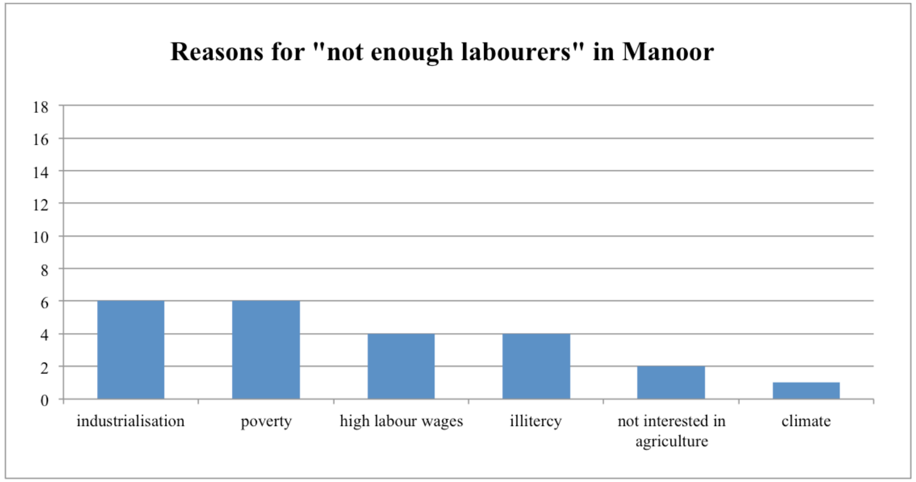


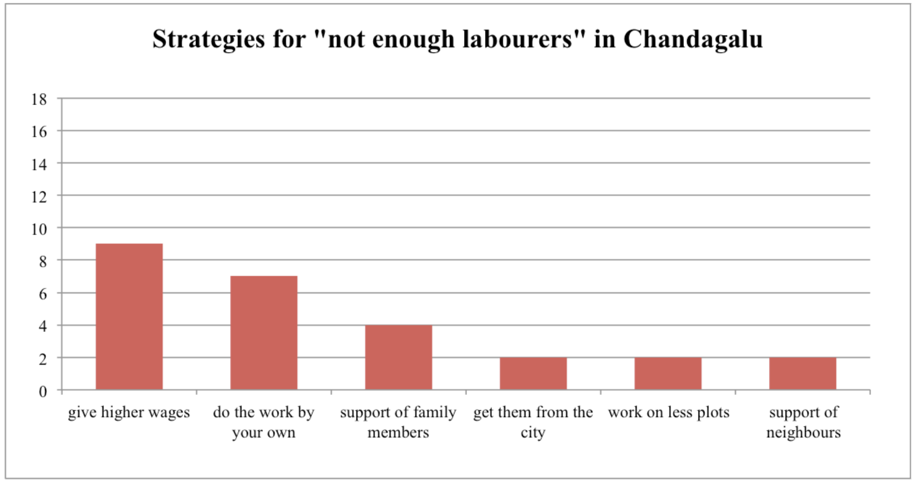


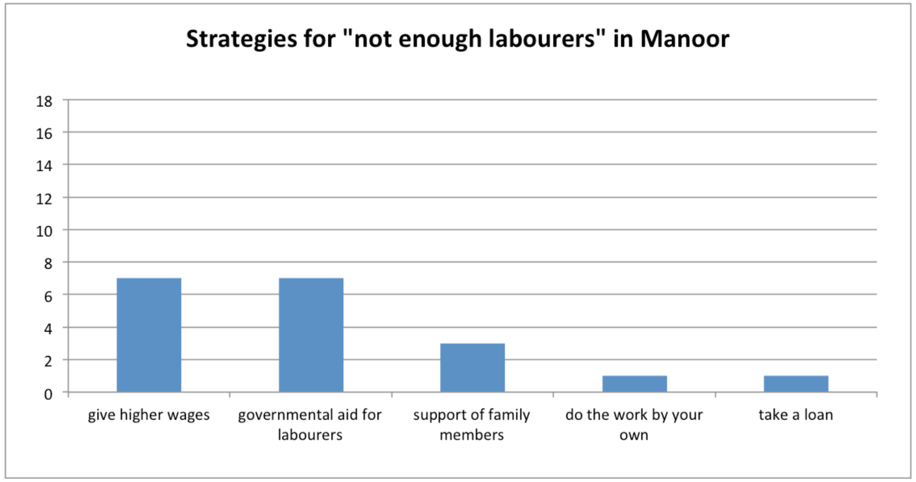


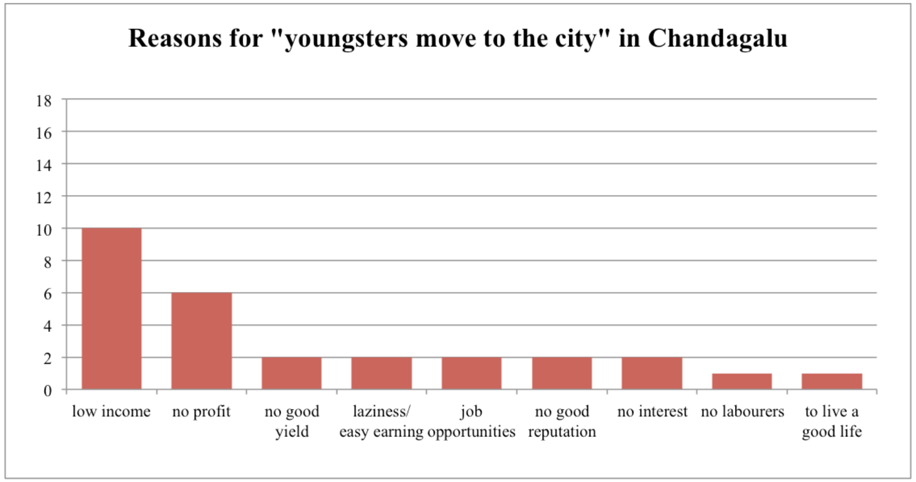


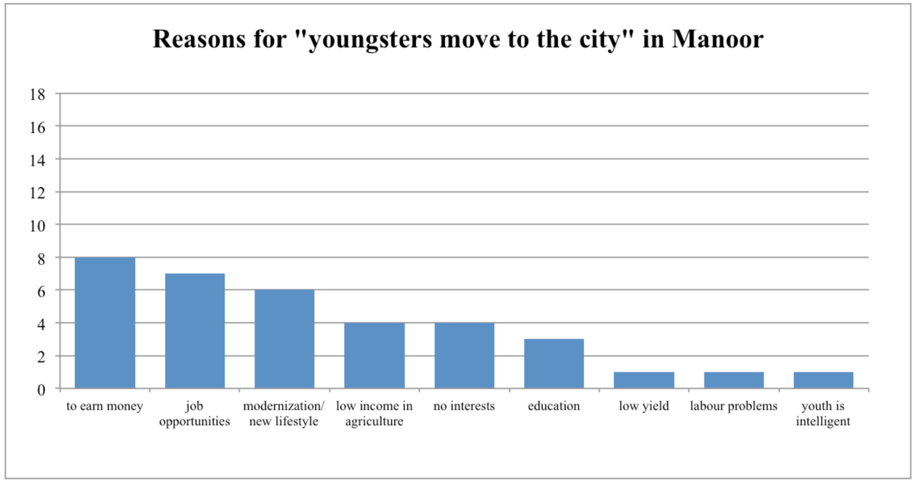

Reasons for "not enough labourers" in Chandagalu
18
16
14
12
10
8
6
4
2
0
1 kg rice for 1 INR
labourers not available at the right time
labouring is not profitable/ low wages
attracted by the city
laziness
no good prices for the yield
water problem

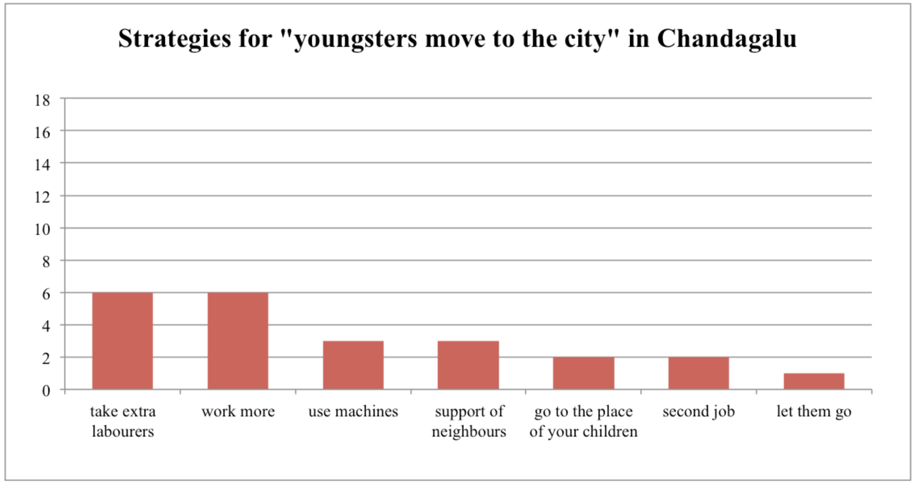

Reasons for "not enough labourers" in Manoor
18
16
14
12
10
8
6
4
2
0
industrialisation
poverty
high labour wages
illitercy
not interested in agriculture
climate

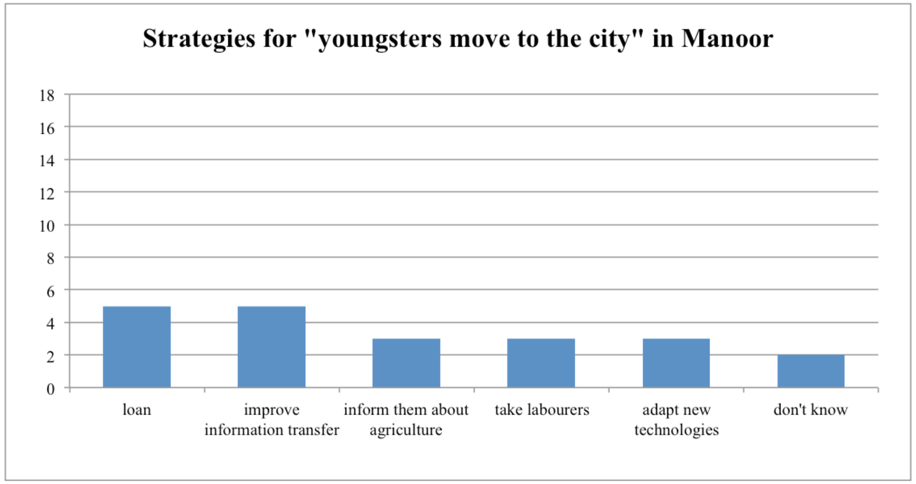

Strategies for "not enough labourers" in Chandagalu
18
16
14
12
10
8
6
4
2
0
give higher wages
do the work by your own
support of family members
get them from the city
work on less plots
support of neighbours

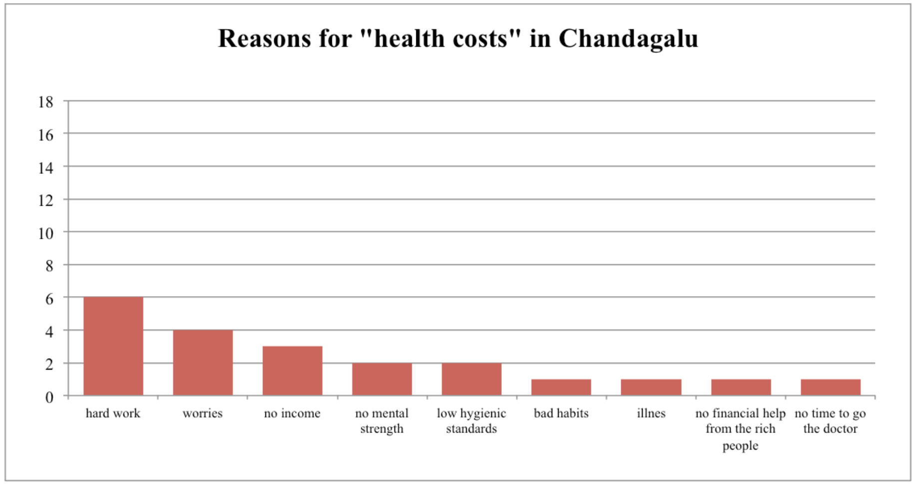

Strategies for "not enough labourers" in Manoor
18
16
14
12
10
8
6
4
2
0
give higher wages
governmental aid for labourers
support of family members
do the work by your own
take a loan

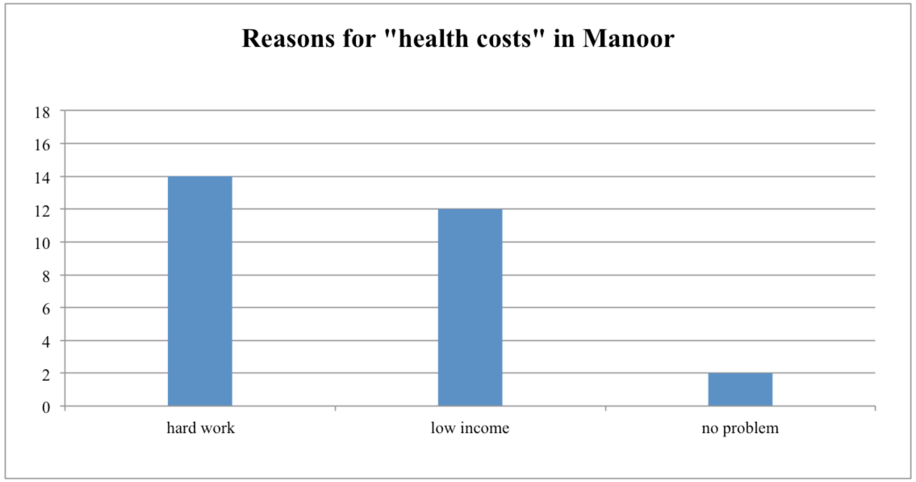

Reasons for "youngsters move to the city" in Chandagalu
0
2
4
6
8
10
12
14
16
18
low income
no profit
no good yield
laziness/ easy earning
job opportunities
no good reputation
no interest
no labourers
to live a good life

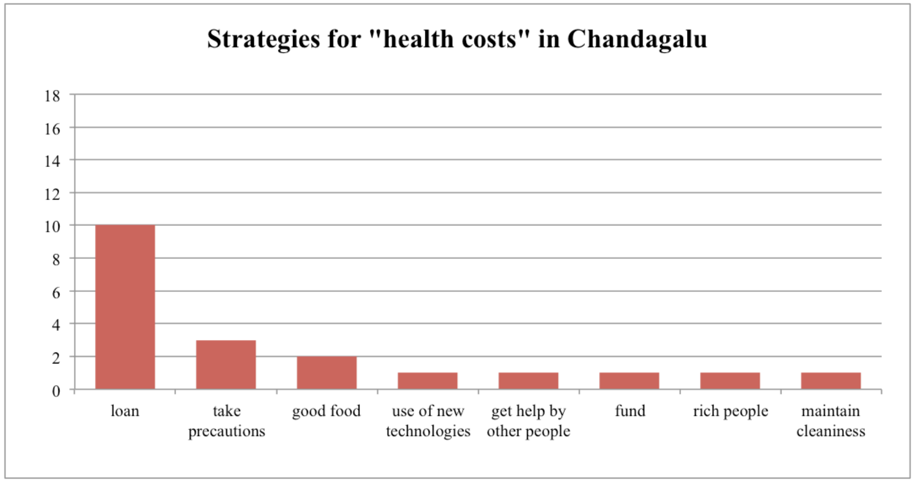

Reasons for "youngsters move to the city" in Manoor
0
2
4
6
8
10
12
14
16
18
to earn money
job opportunities
modernization/ new lifestyle
low income in agriculture
no interests
education
low yield
labour problems
youth is intelligent

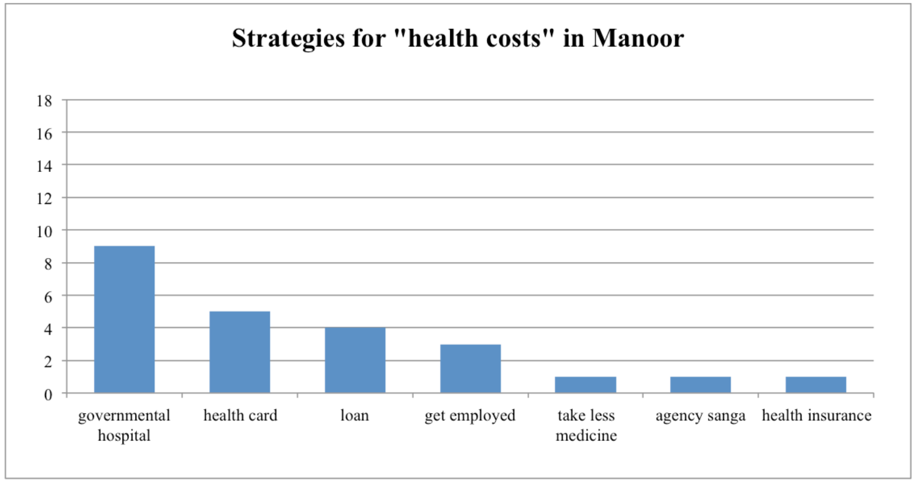

Strategies for "youngsters move to the city" in Chandagalu
0
2
4
6
8
10
12
14
16
18
take extra labourers
work more
use machines
support of neighbours
go to the place of your children
second job
let them go

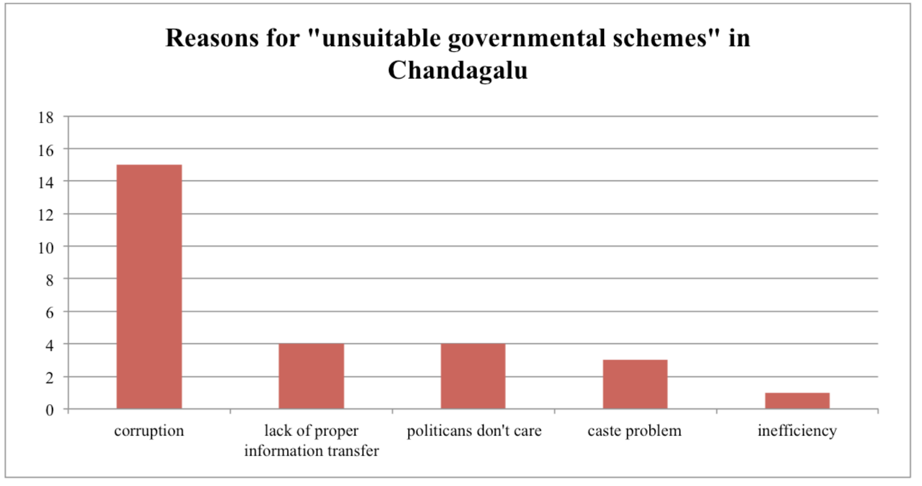

Strategies for "youngsters move to the city" in Manoor
0
2
4
6
8
10
12
14
16
18
loan
improve information transfer
inform them about agriculture
take labourers
adapt new technologies
don't know


Reasons for "health costs" in Chandagalu
18
16
14
12
10
8
6
4
2
0
hard work
worries
no income
no mental strength
low hygienic standards
bad habits
illnes
no financial help from the rich people
no time to go the doctor

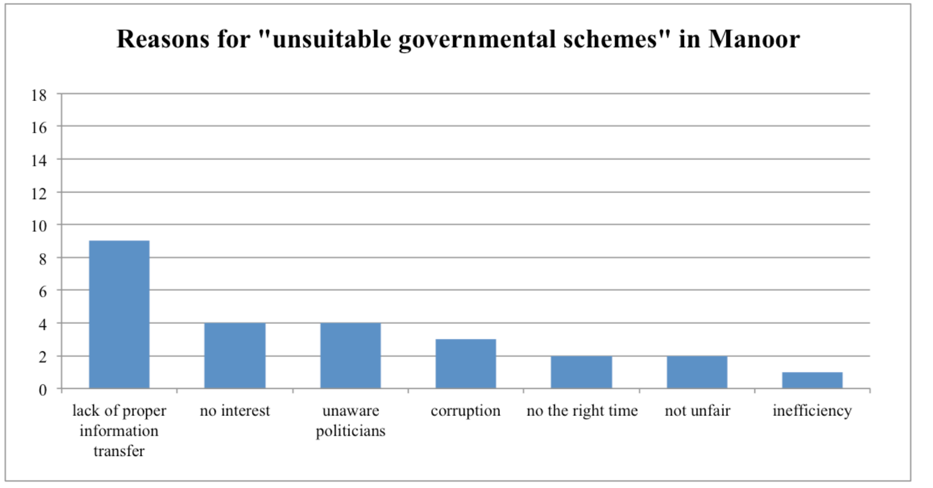

Reasons for "health costs" in Manoor
18
16
14
12
10
8
6
4
2
0
hard work
low income
no problem


Strategies for "health costs" in Chandagalu
18
16
14
12
10
8
6
4
2
0
loan
take precautions
good food
use of new technologies
get help by other people
fund
rich people
maintain cleaniness

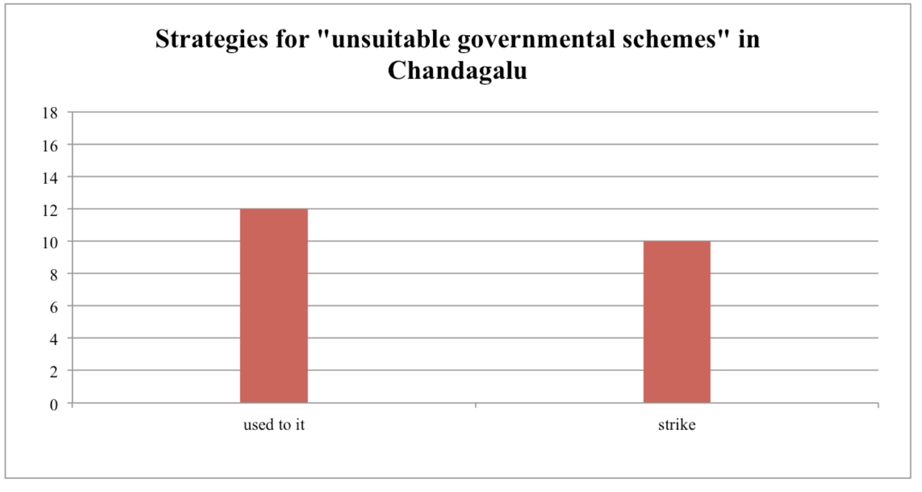

Strategies for "health costs" in Manoor
18
16
14
12
10
8
6
4
2
0
governmental hospital
health card
loan
get employed
take less medicine
agency sanga
health insurance



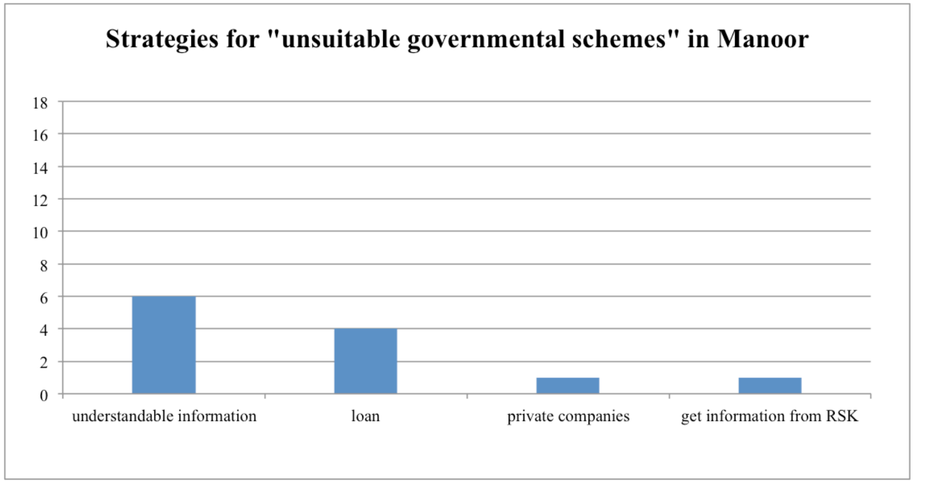
Reasons for "unsuitable governmental schemes" in Chandagalu
18
16
14
12
10
8
6
4
2
0
corruption
lack of proper information transfer
politicans don't care
caste problem
inefficiency



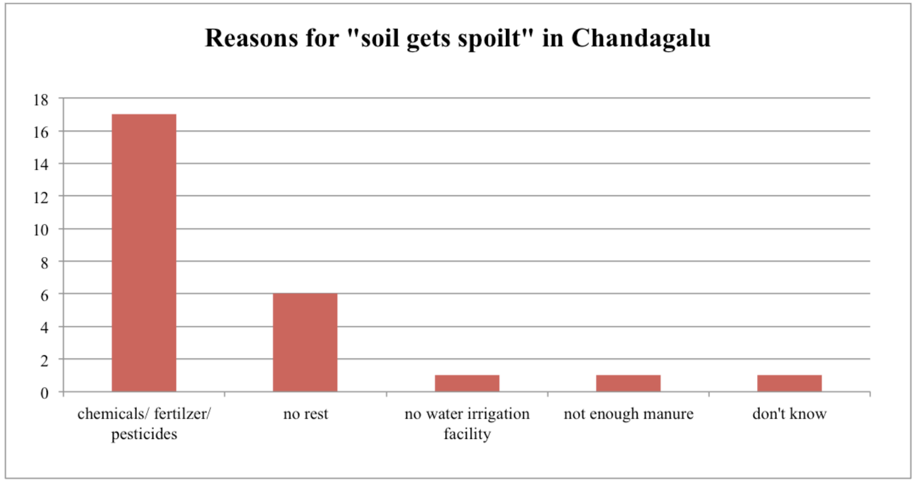
Reasons for "unsuitable governmental schemes" in Manoor
18
16
14
12
10
8
6
4
2
0
lack of proper information transfer
no interest
unaware politicians
corruption
no the right time
not unfair
inefficiency

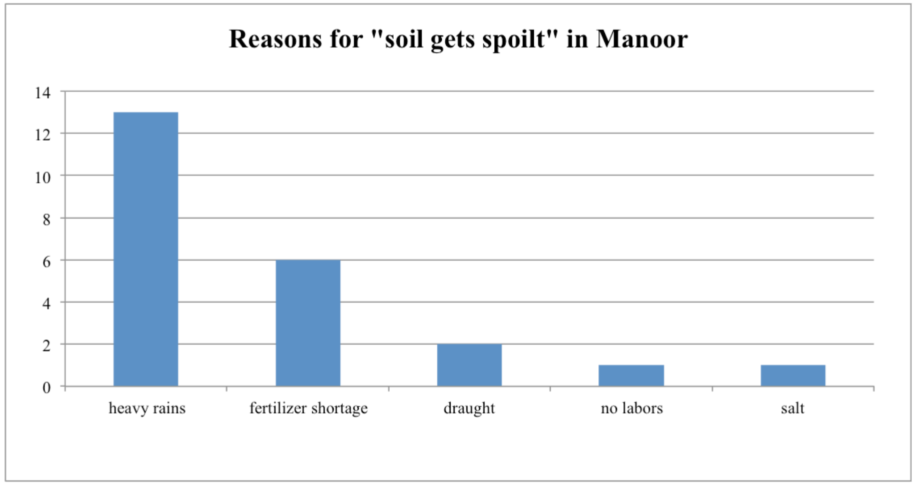


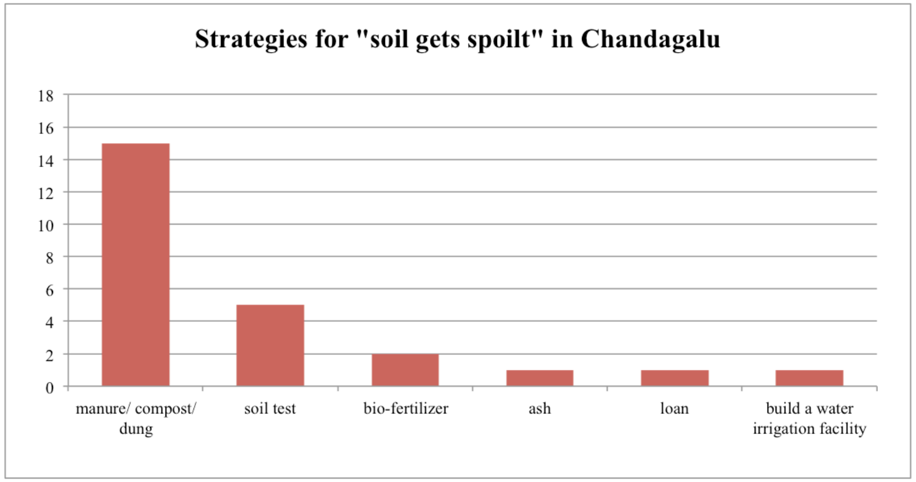
Strategies for "unsuitable governmental schemes" in Chandagalu
18
16
14
12
10
8
6
4
2
0
used to it
strike

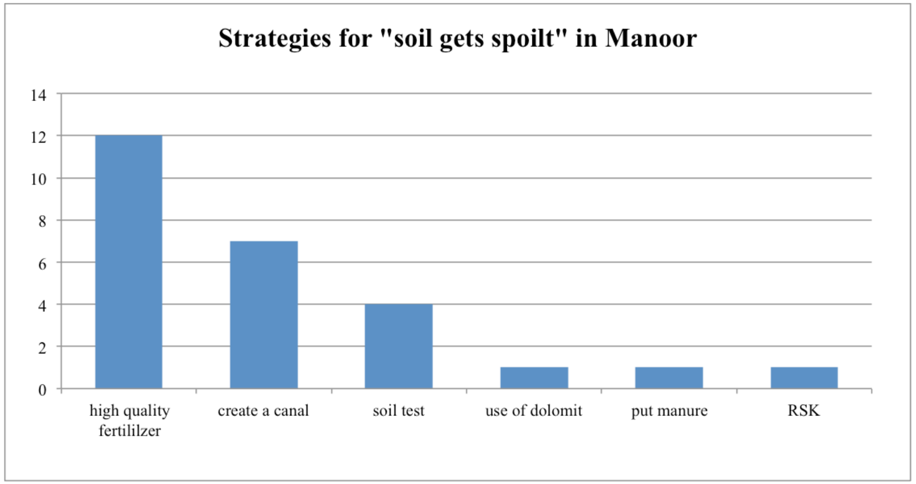


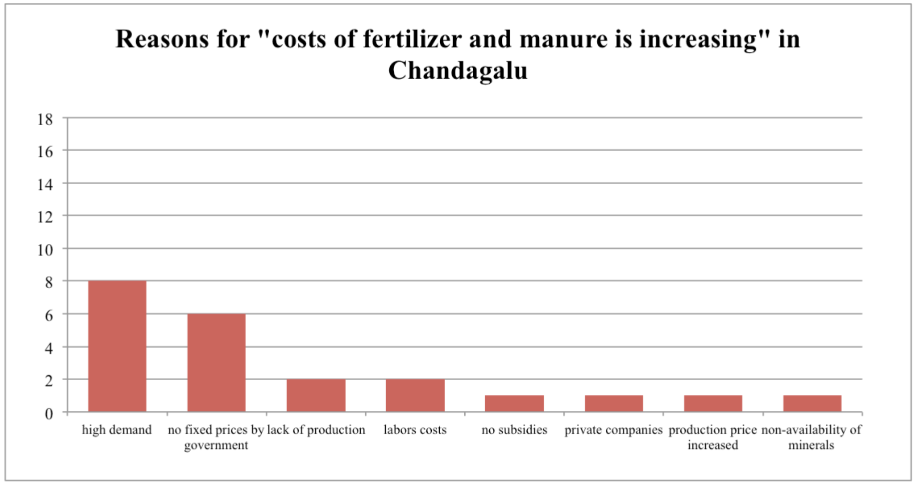
Strategies for "unsuitable governmental schemes" in Manoor
18
16
14
12
10
8
6
4
2
0
understandable information
loan
private companies
get information from RSK

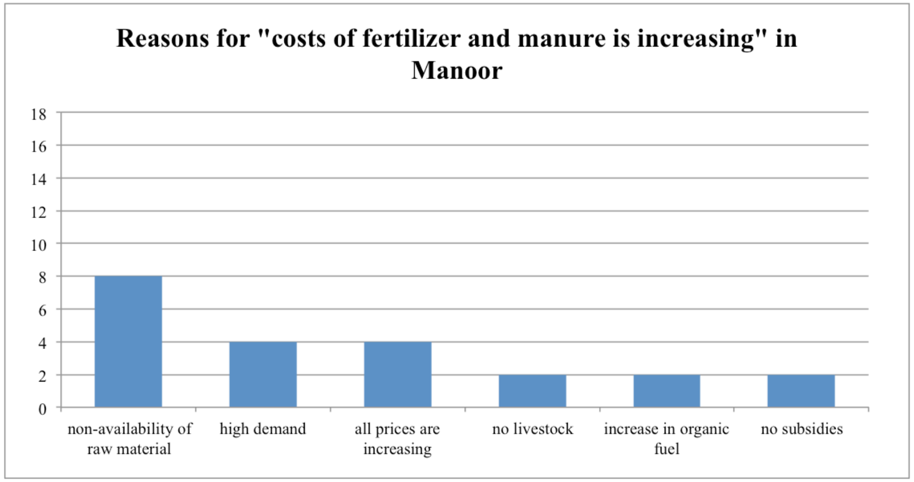

Reasons for "soil gets spoilt" in Chandagalu
18
16
14
12
10
8
6
4
2
0
chemicals/ fertilzer/ pesticides
no rest
no water irrigation facility
not enough manure
don't know

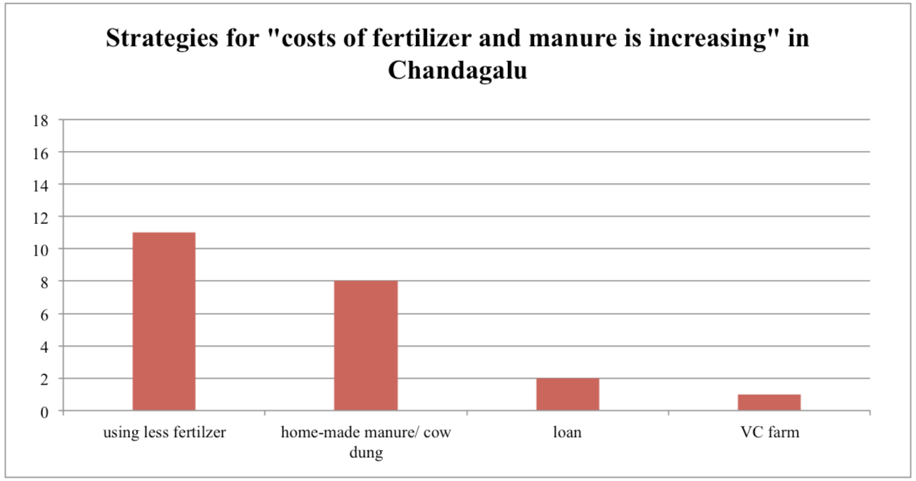

Reasons for "soil gets spoilt" in Manoor
14
12
10
8
6
4
2
0
heavy rains
fertilizer shortage
draught
no labors
salt

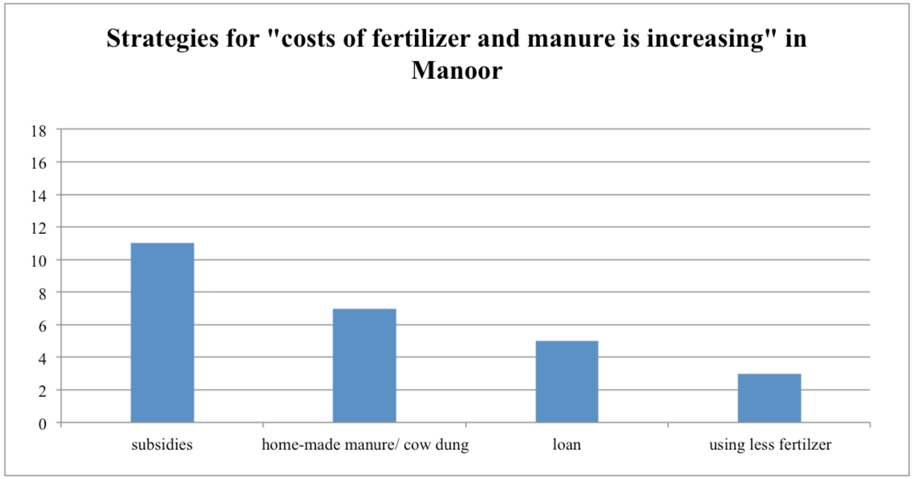

Strategies for "soil gets spoilt" in Chandagalu
18
16
14
12
10
8
6
4
2
0
manure/ compost/ dung
soil test
bio-fertilizer
ash
loan
build a water irrigation facility

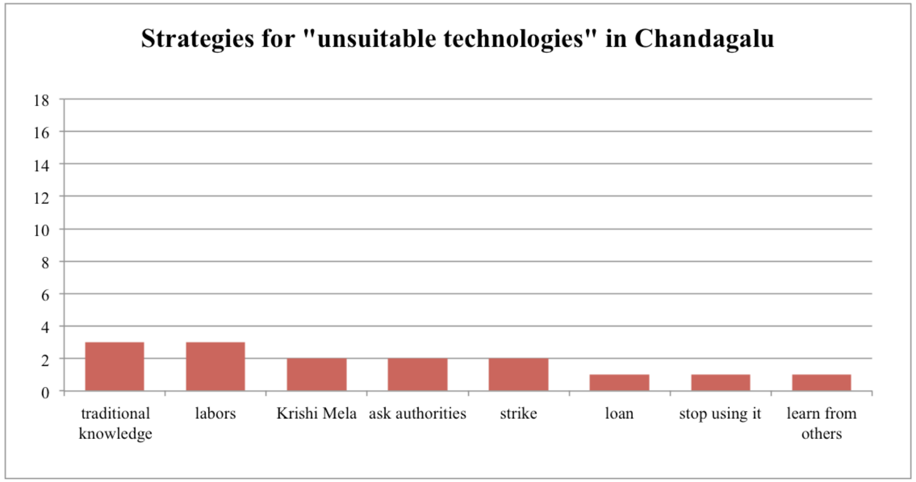

Strategies for "soil gets spoilt" in Manoor
14
12
10
8
6
4
2
0
high quality fertililzer
create a canal
soil test
use of dolomit
put manure
RSK

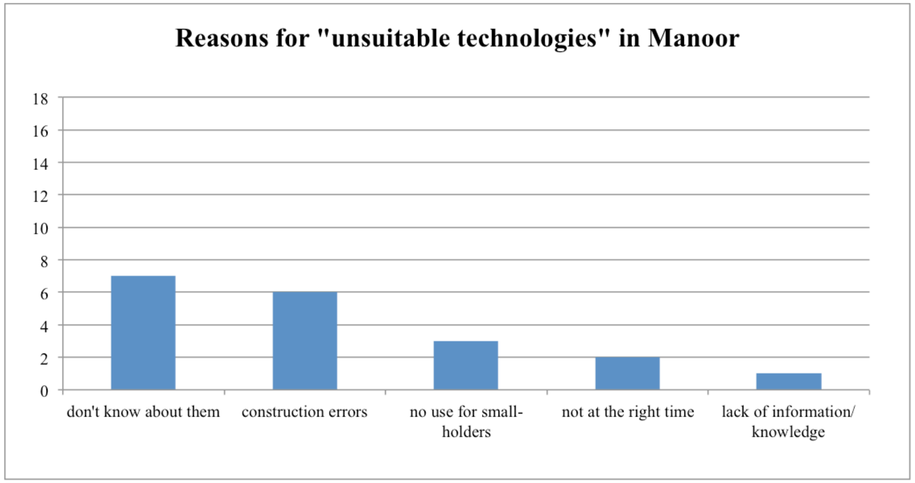

Reasons for "costs of fertilizer and manure is increasing" in Chandagalu
18
16
14
12
10
8
6
4
2
0
high demand
no fixed prices by government
lack of production
labors costs
no subsidies
private companies
production price increased
non-availability of minerals

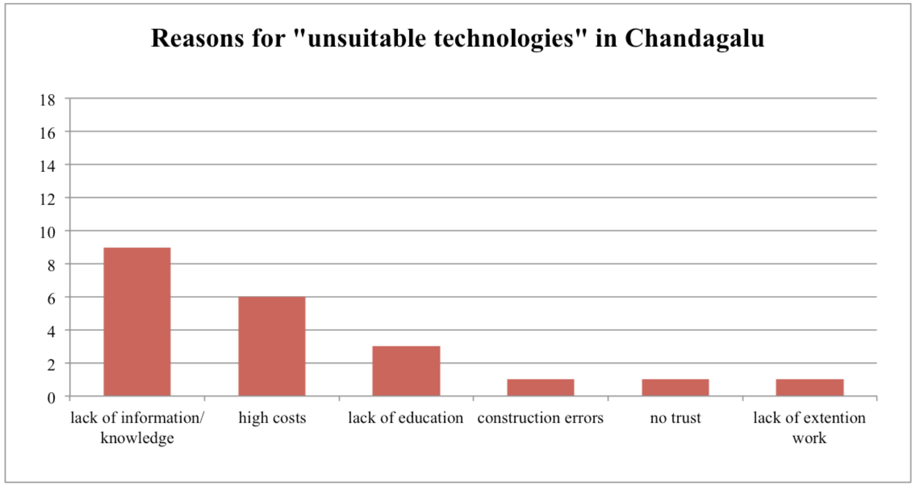

Reasons for "costs of fertilizer and manure is increasing" in Manoor
18
16
14
12
10
8
6
4
2
0
non-availability of raw material
high demand
all prices are increasing
no livestock
increase in organic fuel
no subsidies

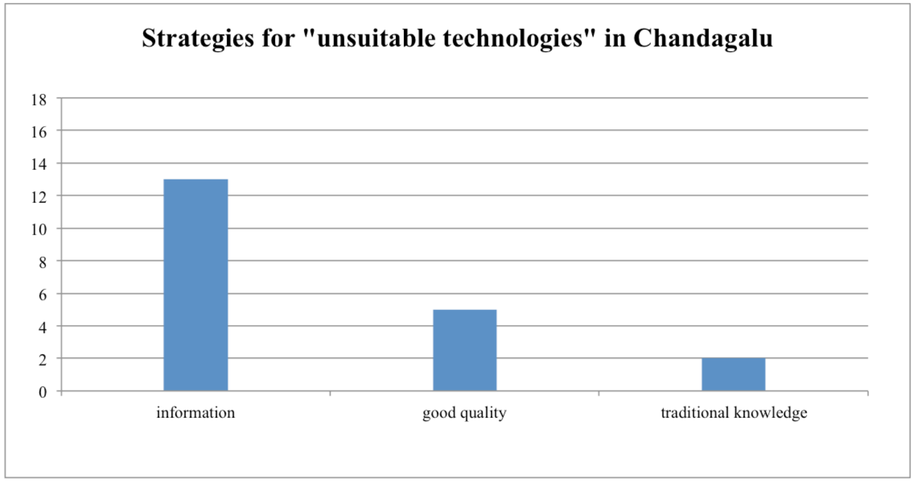

Strategies for "costs of fertilizer and manure is increasing" in Chandagalu
18
16
14
12
10
8
6
4
2
0
using less fertilzer
home-made manure/ cow dung
loan
VC farm


Strategies for "costs of fertilizer and manure is increasing" in Manoor
18
16
14
12
10
8
6
4
2
0
subsidies
home-made manure/ cow dung
loan
using less fertilzer


Strategies for "unsuitable technologies" in Chandagalu
18
16
14
12
10
8
6
4
2
0
traditional knowledge
labors
Krishi Mela
ask authorities
strike
loan
stop using it
learn from others


Reasons for "unsuitable technologies" in Manoor
18
16
14
12
10
8
6
4
2
0
don't know about them
construction errors
no use for small-holders
not at the right time
lack of information/ knowledge


Reasons for "unsuitable technologies" in Chandagalu
18
16
14
12
10
8
6
4
2
0
lack of information/ knowledge
high costs
lack of education
construction errors
no trust
lack of extention work


Strategies for "unsuitable technologies" in Chandagalu
18
16
14
12
10
8
6
4
2
0
information
good quality
traditional knowledge

Annex J: Results of focus groups

Focus Group Soil Science Department of the Agricultural University of Bangalore				
	Sugarcane production/ low quality soil/ dry climate/ small-scale	**Sugarcane production/ low quality soil/ dry climate/ large-scale**	**Sugarcane production/ good quality soil/ dry climate/ small-scale**	**Sugarcane production/ good quality soil/ dry climate/ large-scale**
Investment reasons	• Soil improvement • Increase of nutrient capacity • To increase the water holding capacity • Increase of pH • Helps the small-scale farmer to recycle his releases and improve soil health • Reduction of carbon emission • Increase the appropriateness of the soils and the costs will be less by time	• Production of by-product • Availability of bagasse • Availability of capital to buy a pyrolysis unit	• Increase pore space/ porosity to make the soil more handle • Helps the small-scale farmer to recycle his releases and improve soil health	• Production of by-product • Availability of bagasse • Availability of capital to buy a pyrolyser
Investment constraints	• Uncertain methods, such as rates of application and thus unknown effects on the soil (locking the soil pores); high amounts of manure increases microbioturbation and increases of acid release that can determine the germinating of seedlings) • Recalcitrance of biochar • Distinguish between biochar, (acti-	• No clear distinction between biochar, (activated) charcoal and different organic matter • Uncertain nutrient availability (nitrogen) in biochar/ oil • Heavy metal absorption and effects on human and plants	• No one will add is to black soils, because they are having more water holing capacity • Uncertain methods, such as rates of application and thus unknown effects on the soil (locking the soil pores); high amounts of manure increase microbioturbation and increase of acid release that can determine the germinating of seed-	• No clear distinction between biochar, (activated) charcoal and different organic matter • Uncertain nutrient availability (nitrogen) in biochar/ oil • Heavy metal absorption and effects on human and plants

	vated) charcoal and different organic matter • Uncertain nutrient availability (nitrogen) in biochar/ oil • Organic matter substitute • Heavy metal absorption and effects on human and plants • No money making system for a small-scale farmer • Making of machineries always focused on the large holders, because they are the ones who reach the market • Not enough yield of the small-scale farmer who will sell it to the large-scale farmer and hence large holding farmer is having the bagasse and can pyrolyse it to produce biochar • Availability of bagasse • High monetary and time costs • High initial costs • All organic fertilisation needs time • Uncertain if enough benefits to feed the children		lings) • Recalcitrance of biochar • No clear distinction between biochar, (activated) charcoal and different organic matter • Uncertain nutrient availability (nitrogen) in biochar/ oil • Organic matter substitute • Heavy metal absorption and effects on human and plants • No money making system for a small-scale farmer • Making of machineries always focused on the large holders, because they are the ones who reach the market • Not enough yield of the small-scale farmer who will sell it to the large-scale farmer and hence large holding farmer is having the bagasse and can pyrolyse it to produce biochar • Availability of bagasse • High monetary and time costs • High initial costs • All organic fertilisation needs time • Uncertain if enough benefits to • feed the children	

(Proposed) solutions	• Clear distinguishing methods (temperature, oxygen) • Make a technology available for the small holders and for the large landholders • Make cheap and handy machineries for the small-scale farmers • New technology should start with the small-scale holders • A technology in agriculture should be able to increase the income of the farmers • Large holding farmers pyrolyse it (Jaggery houses, factory producer), can have a bigger unit which is more cost-effective • Patience • Government should support the technology • Simplify the information for the farmers • Sugarcane cooperation (build a cooperative, neighbour farmers come together) • Crop insurances	• Clear distinguishing methods (temperature, oxygen) • Crop insurances	• Clear distinguishing methods (temperature, oxygen) • Make a technology available for the small holders and for the large landholders • Make cheap and handy machineries for the small-scale farmers • New technology should start with the small-scale holders • A technology in agriculture should be able to increase the income of the farmers • Large holding farmers pyrolyse it (Jaggery houses, factory producer), can have a bigger unit which is more cost-effective • Patience • Government should support the technology • Simplify the information for the farmers • Sugarcane cooperation (build a cooperative, neighbour farmers come together) • Crop insurances	• Clear distinguishing methods (temperature, oxygen) • Crop insurances

Focus Group Soil Science Department of the Agricultural University of Bangalore				
	Rice production/ low quality soil/ wet climate/ small-scale	**Rice production/ low quality soil/ wet climate/ large-scale**	**Rice production/ high quality soil/ wet climate/ small-scale**	**Rice production/ high quality soil/ wet climate/ large-scale**
Investment reasons	• Beneficial for the paddy farmer (waste availability)		• Beneficial for the paddy farmer (waste availability)	
Investment constraints	• Usage of waste to feed it to the cattle		• Usage of waste to feed it to the cattle	
(Proposed) solutions				

	Focus group Chandagalu		**Focus group Manoor**
	Focus Group I	**Focus Group II**	**Focus Group III; (IV)**
Investment reasons	• To make profit • To get more yield	• To get a profit	• Soil becomes good • Use of fertilizer is less • To get profit
Investment constraints	• Labourer • High agricultural input costs (high quality seeds, fertilizer, etc.) • Low crop market prices • Capital • Availability of non-farming activities (additional income) • Availability of bagasse • No children in the village (education, no	• Capital • Labourer availability and costs • Place • Boys want to go to the city and don't want not stay in the village • Transportation is difficult, whatever you grow • Middle-men • No help from government, just papers, but	• Capital • Self-believe • Youngster are moving to the city • Soil quality (black, red soil: water capacity on black soil is better) • Labours • Climate (rain not at the right time) • Irrigation • High prices and amount limitations of groundnut

	social value as a farmer) • Health costs • Crop diversity • Low soil quality • Inequality • Schemes are not reaching them • Middle-men are eating the money away • Durability of machines	no profit	seeds • Unequal distribution of groundnut seeds
(Proposed) solutions	• Machines should be provided by government • Use half of the land for farming • Governmental scheme to get free health services (depends on the castes) • Increase of market prices • Get the soil tested • Follow the instructions of the scientists • VC farm should provide high quality seeds at affordable prices • Fair governmental schemes • Subsidies of government • Strike • Biochar and/ or pyrolyser should be affordable • Machines should be durable	• Get a loan • Prices should get down (of input costs) • Get help by VC farm (water and labour usage, seeds, suggestions how to do farming, subsidies) • Biochar and/ or pyrolysis unit should be affordable • Subsidies	• 100% effort • Good yield to make profit to get the people back • Use of cow dung • Governmental scheme to lower the groundnut seed prices and extent the limitations • Get a bank loan, if requirements are fulfilled (land rights, income) • Self-help group (40 member, low interest loan, get help also for the losses, get 30 000 rupies from government) • Being active and fight together for their rights

Personal declaration

I hereby declare that the submitted thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the thesis.