Made in the Shade: a GIS-based Multicriteria-Analysis on Shaded Coffee Certification in Ethiopia

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1. Abstract

Shaded coffee farming, a form of agroforestry, has many ecological benefits such as carbon sequestration, biodiversity conservation, the increase of pollination services, water quality improvement and the countering of soil erosion and depletion. While Ethiopia has a long and unique history of shaded coffee farming, nowadays shaded forest systems are rapidly converted into monocultural non-shaded systems. To create incentives for coffee farmers to use shaded-systems, coffee certification is used to reward farmers for delivered ecosystem services. However, both spatial factors and yield losses are currently not being taken into account in certification leading to unfairness and inefficiency as the rewards are not proportionate to the services. Therefore, it is reasoned that there is a need for more flexible shaded coffee certification that does include spatial factors. This paper will use GIS to create multiple suitability maps of the Southern Nations, Nationalities and People's Region (SNNPR) to determine site-specific costs and benefits showing where certification is most needed. Such a map will contribute to the decision-making on certification, supporting a system that is more fair for both people and nature.

Keywords

coffee forestry, coffee certification, GIS, multi-criteria analysis, Ethiopia

List of abbreviations

GIS: Geographical information systems
MCA: Multi-criteria analysis
SNNPR: Southern Nations, Nationalities and People's Republic

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2. Introduction

2.1 Coffee forestry as a sustainable development tool

Sustainable development requires the need for an increase in agricultural production while simultaneously minimizing the environmental impact of that agricultural production (SDG report, 2018). Relatively little attention has been paid to the usage of agrobiodiversity, cultivating trees in close proximity to agricultural crops, to reach sustainable development goals. Despite little attention in the past, agroforestry is a time-tested practice that has been done in the tropics since the beginning of agriculture (Nair, 2007). Agroforestry provides several ecosystem services of which the major ones are carbon sequestration, biodiversity conservation, countering soil erosion and improving water and air quality (Jose, 2009). Furthermore, studies suggest that agroforestry is a successful strategy to alleviate poverty as the trees can provide an additional source of income and prevent soil degradation (Toledo & Moguel, 2012). A particular interesting crop for agroforestry is Arabica coffee (*Coffea arabica)*, as its shade-tolerance and preference for lower temperatures make it a naturally suitable crop to cultivate under trees (Perfecto et al., 2005). While shaded coffee comprises only a fraction of the global coffee market, this share is substantial in Ethiopia, where about 45% of the coffee production can be classified as shaded (Takahashi & Todo, 2007) Despite many benefits, traditional coffee forestry systems have been consistently replaced by monocultural coffee systems in order to increase the yields.

Figure 1: Sun-grown monocultural coffee (left) and shade-grown polycultural coffee (right) in Ethiopia

Figure 1 shows a visual comparison between sun-grown coffee and shade-grown coffee in Ethiopia. Given the many ecosystem services provided by agroforestry practices, their potential economic benefits for farmers and the wide production of coffee, creating incentives for agroforestry coffee systems provide a large potential to enhance the sustainability of agricultural land.

2.2 Shaded coffee certification schemes

As currently there is a trend of decreasing shade cover to increase coffee yields, conservationists are seeking to find ways to create incentives for farmers to use forest-based systems (Perfecto et al., 2005). Certifying coffee as 'shade-grown' is a market-based tool that rewards farmers for the ecosystem services they deliver by using forest-based systems. The process of certification works by determining a set of criteria that have to be fulfilled in order to certify a product. Besides promoting sustainable agriculture, coffee certification schemes aim to protect farmers against market fluctuations (Perfecto et al., 2007). However, shade-grown certification schemes are criticized for not being effective because of several reasons. Firstly, there is a negative correlation between coffee yield and biodiversity level that is not accounted for in the certification schemes (Perfecto et al., 2005). Due to the low coffee production of certified shaded farmers, these schemes do little in terms of poverty alleviation (Valkila, 2009). Therefore, it is concluded that to improve the livelihoods of coffee farms, both yield and ecosystem services must be accounted for rather than only the second (Perfecto et al., 2005; Gove et al., 2008; Valkila, 2009). Secondly, there are substantial differences in local management among shade-grown coffee farms influencing their ecological benefits (Gove et al., 2008). Currently, there are farms certified as 'shaded' that do in fact not contribute to biodiversity due to the usage of very few tree species. Finally, spatial differences among shaded coffee plantations are not taken into account despite them making substantial differences (Perfecto et al., 2005). To illustrate, Anand et al. (2008) report that the most important factor influencing bird diversity is the proximity to natural forest and other shaded coffee farms. Similar results have been found for pollination services (Priess et al., 2007). Furthermore, not taking into account spatial differences may be counterproductive as it can create incentives for farmers to transform primary forests into coffee plantations (Tejeda-Cruz et al., 2010). Therefore, studies conclude, there is a need for flexible, site-specific certification schemes that reward and compensate farmers more accordingly to improve existing certification schemes (Anand et al. 2008; Gove et al. 2008; Wierson et al. 2012).

2.3 Objective

Despite spatial factors playing a substantial role, they have not been integrated in the allocation processes of coffee certification schemes. To make these certification schemes more efficient, the ‘one size fits all’ approach must be replaced by a site-specific system in which local trade-offs are clear. While many studies have acknowledged this, none have looked into ways of doing this in practice and the usage of geographical information systems (GIS) to facilitate this. In order to fill this gap, this paper will answer the following research question: ‘What are the best locations for certifying shade-grown coffee in the SNNPR region in Ethiopia?’. This question will be answered from the perspective of an NGO in sustainable agriculture wishing to improve the efficiency of current shaded coffee certification with the objective of maximizing ecosystem services and poverty alleviation for minimal economic costs. The chart illustrated in Figure 2. summarizes the research question as well as relevant sub-questions that will be answered in this study. Firstly, this study will use GIS to map the value of the land of the Southern Nations, Nationalities and People’s Republic (SNNPR) in terms of potential yield loss, biodiversity level, landslide risk, flood risk, drought risk, poverty level and future temperature changes due to climate change to finally come to a coffee certification suitability map of the region. Then, these results will be combined in a final suitability map by doing a multi-criteria analysis. Having such a map is a useful tool in the allocation of certification because it indicates the explicit costs and benefits per location. While the scope of this study is the SNNPR region in Ethiopia, the methodology of this study can be used for other coffee regions in- and outside Ethiopia. Using GIS and multi-criteria analysis to improve current coffee certification systems, ultimately supports the building of fairer coffee production for both people and nature.

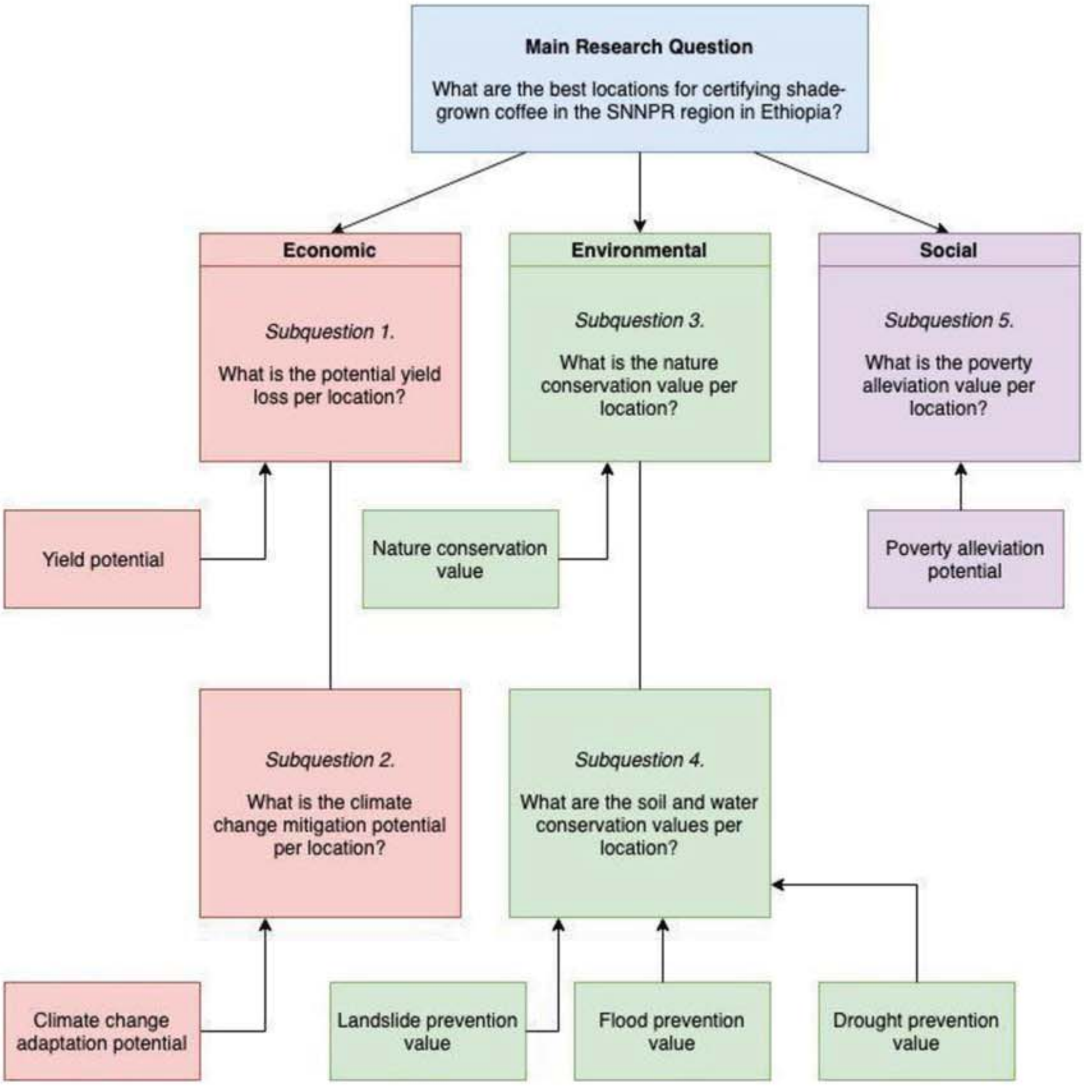


Figure 2: Chart describing research questions and sub-questions categorized as 'economic', 'environmental' and 'social'. For each of the sub-questions the criteria are indicated.

3. Methodology

3.1 Study area

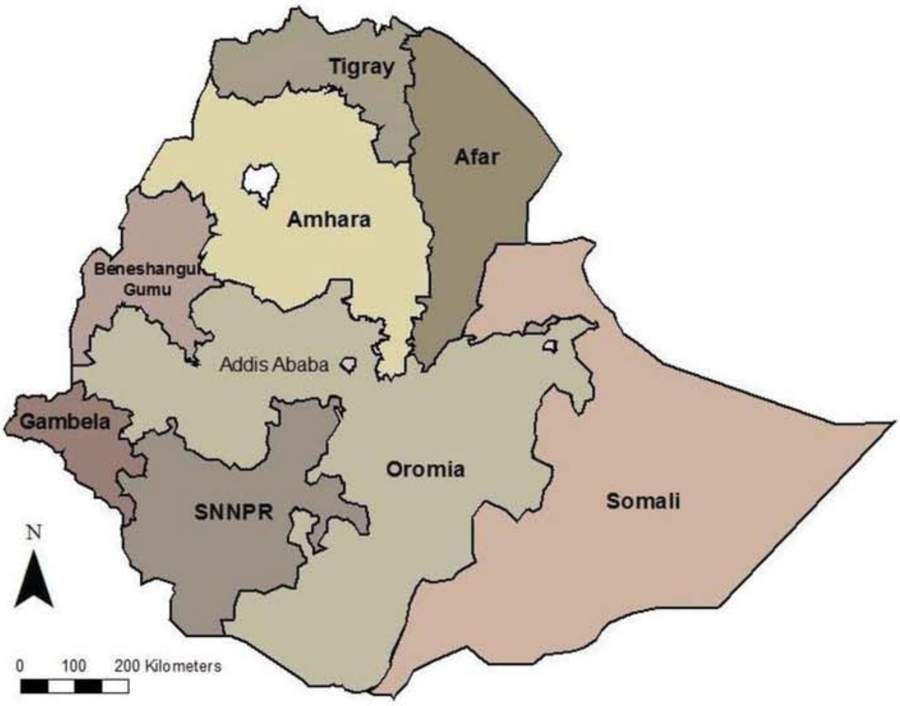


Figure 3: The regions of Ethiopia. The Southern Nations, Nationalities and People's Republic (SNNPR) is located in the southwest bordering Oromia and Gambela.

The SNNPR is located in the south of Ethiopia and compromises an area of 110.000 km^2 which corresponds to 10% of the total area of the country. The region is divided into 23 administrative zones. In 2017, the population was estimated by the Ethiopian Central Statistical Agency to be 19 million (CSA, 2017). The standard of living in the SNNPR is low with 62.2% of the people earning less than \$3.20 per day (CSA, 2017) Ethiopia, including the SNNPR, is high in biodiversity and contains two of the world's 34 biodiversity hotspots: the Eastern Afromontane and The Horn of Africa. However, the SNNPR has seen rapid deforestation with a decline of 26% between 1986 and 2006 (Aseffa & Bork, 2013). Attempts by the government to curb these trends are mainly done by means of establishing so-called protected areas. In the SNNPR, there are seven established national parks: Oromo, Nech Sar, Mago, Chebera Churchura, Maze, Gibe Sheleko and Loka Abaya.

The SNNPR has a long-standing history of coffee production as the wild *Coffea arabica* originates in this area (Senbete & Denich, 2006). Arabica coffee plays a central role in the Ethiopian economy as it is estimated that the livelihoods of about 15 million people directly depend on it (Labouisse et al., 2008). By tradition, this crop has been managed in a forest system by decreasing the tree density to increase the coffee yield (Senbete & Denich, 2006). Four major types of coffee systems are commonly distinguished in the area: forest, semi-forest, garden and plantation (Labouisse et al., 2008). The forest coffee system includes minimal human intervention with the forest. The semi-forest system includes the removal of weeds, lianas and competing scrubs and usually only thin trees. Garden coffee refers to the cultivation of coffee on smallholdings, often together with other crops such as fruit trees. Finally, plantation coffee concerns coffee that is cultivated in a monoculture on cleared land that is closely managed to maximize production (Labouisse et al., 2008). In this study, the emphasis will lie on the first type of plantation.

3.2 GIS-based Multicriteria-analysis

To create a suitability map for shaded coffee certification, different datasets are combined in a geodatabase. First, all areas that are considered unsuitable for certification are excluded. Two types of land can be distinguished: (i) land that cannot be converted to coffee plantations such as build-up land (ii) land that is covered with natural forest. The second type of land is excluded to prevent further deforestation. Then, all land remaining land is evaluated based on different criteria. A criteria within MCA is defined as a standard of judging that evaluated by measurable parameters (Geneletti, 2006). In this study, the following criteria are used to determine the suitability of a location for shaded coffee certification: yield potential, climate change impact, biodiversity level, landslide risk, flood risk, drought risk and poverty reduction (Figure 3). Finally, a suitability map is derived by using the following function:

$$S = \sum w_i x_i$$

This commonly used function combines weighted preferences (w_i) and criterion scores (x_i). 'Shaded' coffee production is defined in this study as any coffee system in which there is >70% tree cover. This threshold has been chosen because studies suggest that this tree cover percentage needs to be reached to significantly influence its impact on biodiversity (Anand et al., 2008). Finally, policy recommendations based on this suitability map are discussed.

3.3 Value tree

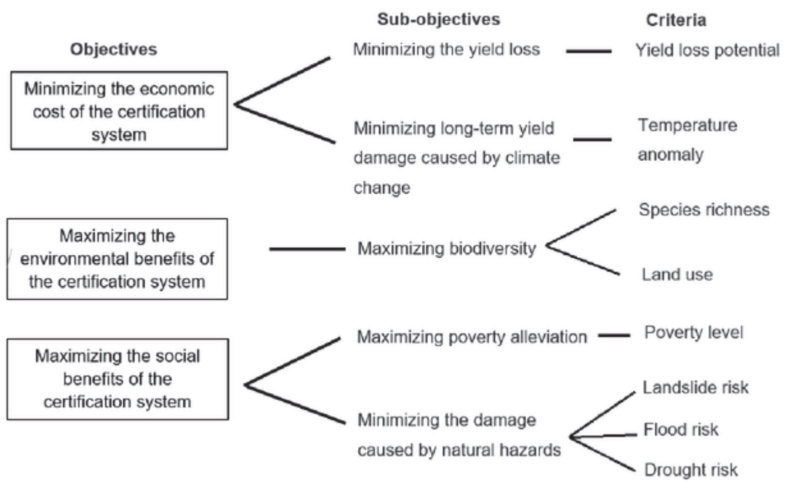


Figure 4: Value tree for evaluating the suitability for coffee certification

Figure 4 depicts the value tree that is used to evaluate the suitability of the SNNPR region for coffee certification.

3.4 Criteria

It is reasoned that the higher the suitability for coffee farming, the higher the value of the potential yield. As increasing the tree density in a coffee farm is negatively correlated to yield, it would be more costly to practice coffee forestry in areas that have a high yield potential. The coffee yield potential in this study is determined by five factors: elevation, rainfall, temperature, soil type and slope. Based on scientific literature on the optimal conditions for coffee production, the factors are classified and assigned scores on a scale 1-5. The classification system is summarized in Table 1.

Table 1: Classification of factors influencing coffee production

Elevation (m)	Precipi-tation (mm)	Temp (C)	Soil Type*	Slope (%)	Score	Yield potential
1600-1800	1400-1600	18-20	CH, KS, PH, AN	0-4	5	Very high
1400-1600, 1800-2000	1200-1400, 1600-1800	16-18, 20-22	LV, LX	4-12	4	High
1200-1400	1000-1200, 1800-2000	15-16, 22-24	CM, UM	12-25	3	Moderate
1000-1200, >2000	800-1000, <2000	14-15, 24-26	FR, PL	25-50	2	Low
<1000	<800	<14, >26	HS, VR	>50	1	Very low

*All abbreviations for soil types are according to the World Reference Base as developed by the FAO

Finally, the following function is used to determine the yield potential:

1. Yield potential = 0.2*elevation+0.2*precipitation+0.2*temperature+0.2*soil_type+0.2*slope

Elevation data with 90m resolution has been taken from the CGIAR Consortium for Spatial Information (CGIAR-CSI) and was originally produced by NASA as part of the Shuttle Radiation Topography Mission (SRTM) launched in 2000. Precipitation and temperature data of 2019 was taken from the National Center for Atmospheric Research (NCAR). Vector data of the different soil types and slopes within the SNNPR has been obtained from the FAO-UNESCO global soil map of 2007.

Biodiversity conservation

Multiple studies conclude that the distance between coffee plantations and natural forest is the strongest factor influencing the conservation value of the farm (Anand et al., 2008; Dolia et al., 2008). Thus, the closer a coffee plantation to a natural forest, the higher the conservation value of that coffee plantation. Reason for this is that the forests of Ethiopia are heavily fragmented, making the remaining patches too small to sustain plant and animal diversity (Hundera et al., 2013). Coffee farms can serve as refuges and corridors to increase the connectivity of the remaining forest patches (Asare et al., 2014).

The following function is used to evaluate conservation and pollination services of a shaded coffee farm at a particular point:

2. Conservation value = 0.33*amphibians 0.33 *birds+0.33*mammals

Data from 2015 with 1-km cell resolution on amphibian and mammal species richness has been taken from the Socioeconomic Data and Applications Data Center (SEDAC), which is part of NASA. Bird species data from 2006 was taken from the World Wildlife Fund (WWF) database of species distribution.

Soil and water conservation

The soil and water conservation functions refer to the prevention functions of landslides, floods and droughts. Landslides and floods in Ethiopia are both increasing in frequency and cause damages by destroying houses, roads and agricultural land (Ayalew, 1999; Billi et al. 2014). Coffee forests prevent landslides by retaining material in situ and limiting the extent of disturbance after it has already been set in motion (Sakals et al., 2006). Besides landslides and floods, climate models predict drought probability to increase due to climate change (IPCC, 2007). In the past, droughts have led to crop failures and widespread food shortages in East Africa (Evangelista et al., 2013). Shaded coffee systems are a means to adapt to these projected droughts by increasing the water infiltration and retention of the soil to reduce water stress (Swamy & Tewari, 2017). The more prone an area is to landslides, floods and droughts, the more advantageous it is to create incentives for shaded coffee plantations. Based on scientific literature on the influence of geological and soil features on landslides, floods and droughts (Phua and Minowa, (2005), various factors were assigned scores according to the following Table:

Table 2.1, 2.2 and 2.3: Classification of factors influencing the occurrence of landslides, floods and droughts

Slope	Annual rainfall (mm)	Soil depth (m)	Lithology	Topology	Score	Landslide risk
>30%	> 4000	>1	Igneous (granite)	Convergence	3	High
8-30%	3000-4000	0.5-1	Igneous (ultrabasic)	-	2	Medium
0-8%	< 3000	< 0.5	Volcanic origin, alluvium	Divergence	1	Low

Slope	Annual rainfall (mm)	Soil depth (m)	Lithology	Topology	Score	Flood risk
>30%	> 4000	>1	Igneous (granite)	Convergence	3	High
8-30%	3000-4000	0.5-1	Igneous (ultrabasic)	-	2	Medium
0-8%	< 3000	< 0.5	Volcanic origin, alluvium	Divergence	1	Low

Slope	Annual rainfall (mm)	Soil depth (m)	Lithology	Topology	Score	Drought risk
>30%	> 4000	>1	Igneous (granite)	Convergence	3	High
8-30%	3000-4000	0.5-1	Igneous (ultrabasic)	-	2	Medium
0-8%	< 3000	< 0.5	Volcanic origin, alluvium	Divergence	1	Low

Then, the factors were combined using the following functions:

3. Landslide prevention value=
   0.3*slope+0.2*annual_rainfall_0.2*soil_depth+0.15*lithology+0.15*topography

4. Flood prevention value=
   0.2*slope+0.2*annual_rainfall_0.25*soil_depth+0.15*lithology+0.2*topography

5. Drought prevention value=
   0.1*slope+0.25*annual_rainfall_0.3*soil_depth+0.15*lithology+0.2*topography

Slope data was derived from the FAO-UNESCO soil map of Africa of 2009 that put slope data in three categories: 0-8%, 8-30% and >30%. Precipitation data was taken from the National Center for Atmospheric Research (NCAR). Data on the soil depth was taken from NASA. Lithology data was taken from the US Geological Survey (USGS). Topography data was derived from the GTOPO30, which is a global digital elevation model (DEM) developed with 30-arc second resolution. Firstly, the commonly used D8 algorithm has been used to calculate flow directions. Then, using this data on flow direction, the flow accumulation has been derived and classified into ‘accumulation’.

Poverty alleviation potential

As sub-regional data on poverty in Ethiopia is scarce, food insecurity is used as a proxy variable. Food insecurity can serve as a proxy variable due to the close correlation between food insecurity and the official poverty measure (Wight et al., 2014). Data from 2019 was taken from the Famine Early Warning Systems Network (FEWS NET), an organization that maps food insecurity in terms of the following levels: minimal, stressed, crisis, emergency and famine. These categories have been scored as following:

Table 3: the scoring of the different levels of food security

Food security status	Poverty alleviation potential
Minimal	1
Stressed	2
Crisis	3
Emergency	4
Famine	5

The scoring system that is used in this analysis is based on the notion that the poorer an area is the more suitable that area is for certification. This system is used because of two reasons: 1. poverty alleviation is besides nature conservation the main objective coffee certification, hence it is sensical to target poorer areas and 2. mitigating deforestation by means of certification is empirically shown to be more effective in poor areas (Perfecto, 2005).

Climate change adaptation potential

Different studies have concluded that climatic changes will significantly impact crop production in Ethiopia (Perfecto et al., 2005; Deressa and Hassan, 2009). A study by Moat et al. (2017) resulted in the notion that under various climate scenarios 39-59% of the current coffee regions can become unsuitable for coffee production. However, they concluded that coffee forestry could increase the suitable area for coffee production by more than 400% (Moat et al., 2017). Scenarios of climate change will have different impacts within Ethiopia due to its geological and climatological diversity. Since literature describes coffee forestry as a useful adaptation tool, areas that are more impacted by climate change are considered more suitable for shade-grown coffee certification.

To measure the impact of climate change in the SNNPR, current maximum temperatures were compared to maximum temperatures in 2050 derived from the INMCM4.0 model. Current maximum temperatures served as reference values from which the temperature anomalies were calculated. As a scenario for future carbon emissions, Representative Concentration Pathway 8.5 was chosen in which emissions continue to rise throughout the 21st century as it represents the worst-case scenario in terms of climate change impacts (AR5). Both datasets on current and future temperatures with 10km resolution were derived from WorldClim (2005).

3.5 Weighting of the criteria

Table 4: Summary of the criteria weighting

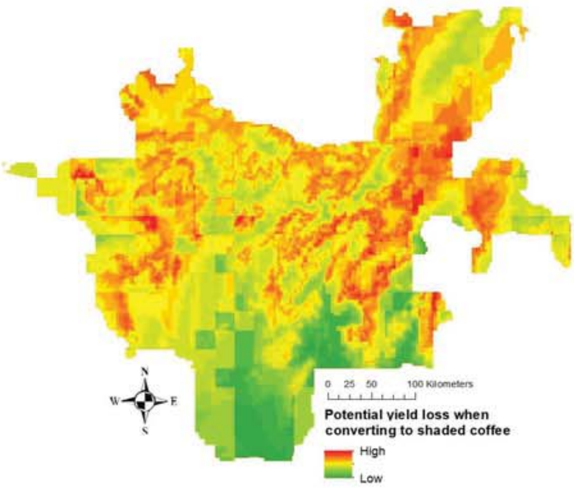
Objective	Criterion	Indicator (unit)	Normalization	Weight
Economic	Yield potential	-	Min-max normalization	15
	Climate change adaptation potential	Temperature anomaly (℃)	Min-max normalization	5
Environmental	Nature conservation potential	Number of species	Min-max normalization	35
Social	Landslide prevention potential	-	Min-max normalization	8.75
	Flood prevention potential	-	Min-max normalization	8.75
	Drought prevention potential	-	Min-max normalization	8.75
	Poverty alleviation potential		Minimal: 3,33 Stressed: 6,67 Crisis: 10	8.75

Table 4 summarizes the weighting of the criteria. The environmental and social objectives were considered equally important and were each assigned weight 40. This is done as these are considered the main objectives for coffee certification. Moreover, the criteria within the social objective are given equal weights as well. While there are possible differences between the impact coffee forestry can have on the risks of different natural disasters, these differences are uncertain. Similarly, it is not possible to rank the different natural disasters according to their impact on local people as this is very context-dependent. The economic objective is given weight 20, of which 15 is attributed to the yield potential and 5 to the climate change adaptation potential. The reason for this is the lack of certainty in climate modelling on local levels. Even though it is clear that global warming negatively affects coffee production, it is uncertain what scenario accurately describes future changes. Furthermore, there is a high degree of uncertainty in the modelling of small-scale temperature increases and precipitation changes.

4. Results

4.1 Value maps

Figure 5.1 and 5.2: potential yield loss in case of conversion to shaded coffee system within the SNNPR (left) and predicted temperature anomalies for 2050 within the SNNPR (right)



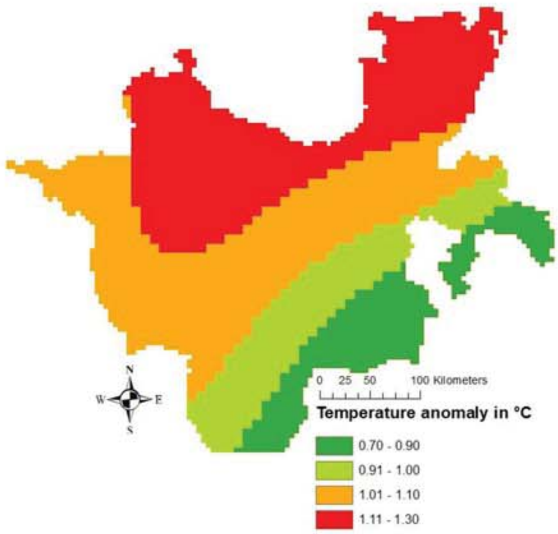


Figure 5.1 (left) shows the potential yield loss in case of conversion to a shaded coffee system. The red areas in the northeast and west are more expensive to convert to shaded coffee systems as there is a larger difference between the yields of monocultural systems and shaded systems. This translates into a higher premium price to compensate for yield loss. The green areas in the south are less expensive to convert into shaded coffee systems as a lesser yield is expected from monocultural systems. This, in turn, leads to a lower premium price as yield loss to be compensated for is lower. According to this reasoning, it more cost-effective to certify in the southern parts of the SNNPR. Figure 5.2 (right) shows the predicted temperature anomaly in 2050 compared to now. In the north and northwest, it is estimated that temperature will increase with 1.1-1.3°C. In the central areas, temperatures will rise with 0.9-1.1°C. In the southern areas, climatic changes have the smallest impact in terms of temperature changes with an anomaly of 0.7-0.9°C. These temperature rises are related to changes in weather patterns that have adverse effects on coffee farming (Moat et al., 2017). Agroforestry can mitigate long-term

economic damages. Therefore, are areas that are relatively more impacted by climate change considered more economically attractive for shaded coffee systems.

Figure 5.3 and 5.4: Species richness within the SNNPR (left) and the level of landslide risk within the SNNPR (right)

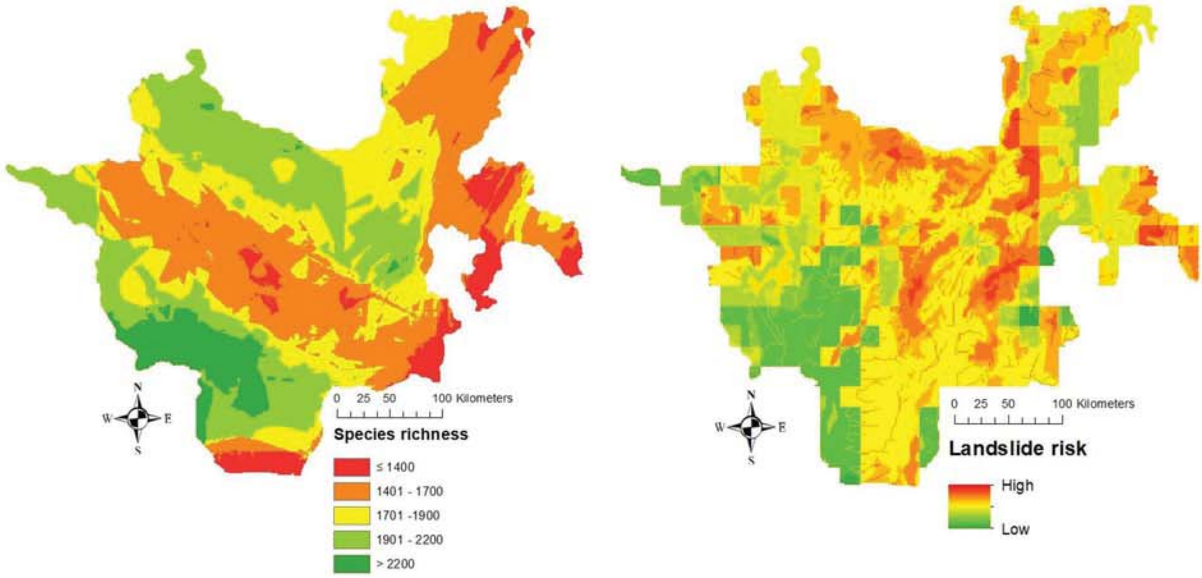
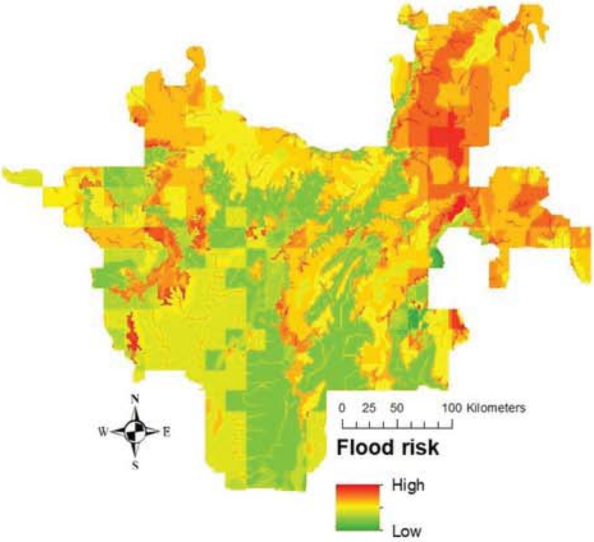


Figure 5.3 (left) shows the total number of amphibian, mammal and bird species summed up. It does not regard plant and other animal species. The southwestern parts of the SNNPR are the highest in species richness, which may be attributed to the presence of the Oromo National park, the largest national park within the SNNPR. In this area, there are more than 2200 different species to be found. Other areas that are high in species richness are the northwestern parts with between 1900 and 2200 different species. The central and eastern areas of the SNNPR are the lowest in species richness. Figure 5.4 shows the levels of landslide risk within the SNNPR. The landslide risk is the highest in the north-central parts, which may be attributed to high erosion levels as well as the presence of steeper slopes (Philips & Marden, 2012). High erosion levels are, in turn, often caused by deforestation as a result of agricultural expansion (Philips & Marden, 2012). Vice versa, landslide risks are lower in the south-western parts of the SNNPR that are characterized by woodlands.

Figure 5.5 and 5.6: Level of flood (left) and drought (right) risk within the SNNPR



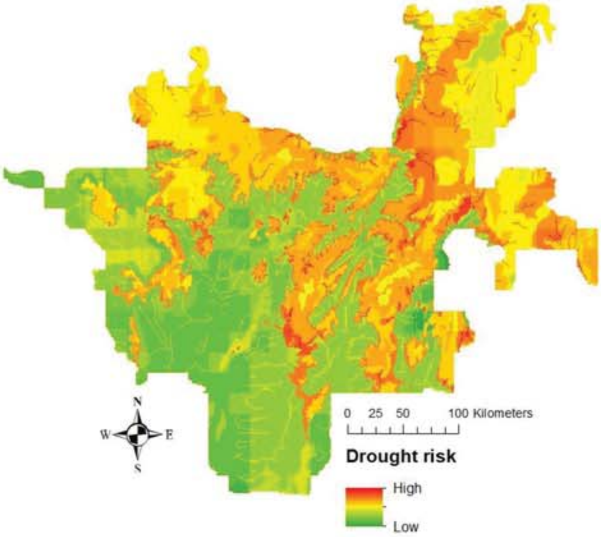


Figure 5.5 (left) shows the levels of flood risk within the SNNPR. Similar to landslide risks, flood risks are higher in the northeastern parts of the SNNPR. Floods are like landslides caused by, among other factors, erosion levels (Boardman et al., 2003). The southern parts of the SNNPR exhibit lower levels of flood risk. Drought risk levels are indicated in Figure 5.6 (right). The lowest drought risk levels are found in the southwestern parts of the SNNPR and the highest levels are found in the northeast. Potential reasons for this may be the higher precipitation rates in the southwest as well as the lack of steep slopes.

Figure 5.7: Poverty levels within the SNNPR

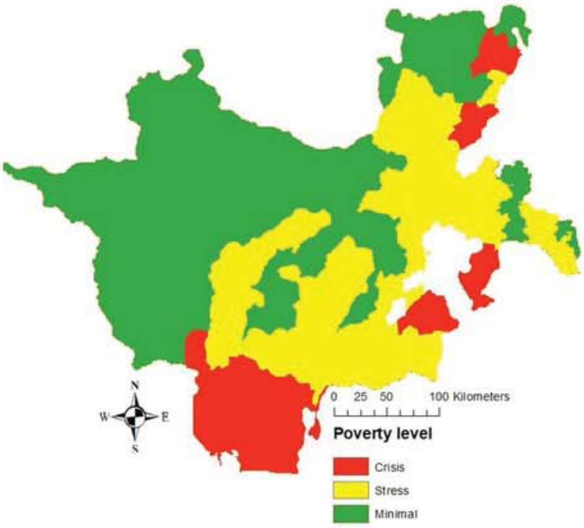


Figure 5.7 shows a map of the SNNPR, indicating three levels of poverty. These levels are directly interpolated from the different degrees of food insecurity as assessed by FEWS NET. The southern part of the SNNPR as well as some small parts in the east and north are characterized as 'crisis', which means that households are hardly able to meet minimum food needs. The eastern part of the SNNPR is characterized as 'stressed', which indicates that households are able to meet minimum food needs but cannot afford essential non-food products. The western areas in the SNNPR are characteristic as 'minimum', indicating that households are able to meet minimum food requirements as well as minimum non-food requirements. It is assumed that these food insecurity levels are directly correlated to poverty levels.

4.2 Suitability maps

Figure 6.1 and 6.2: suitability for shaded coffee certification based on the potential yield losses (left) and the climate change adaptation potential (right)

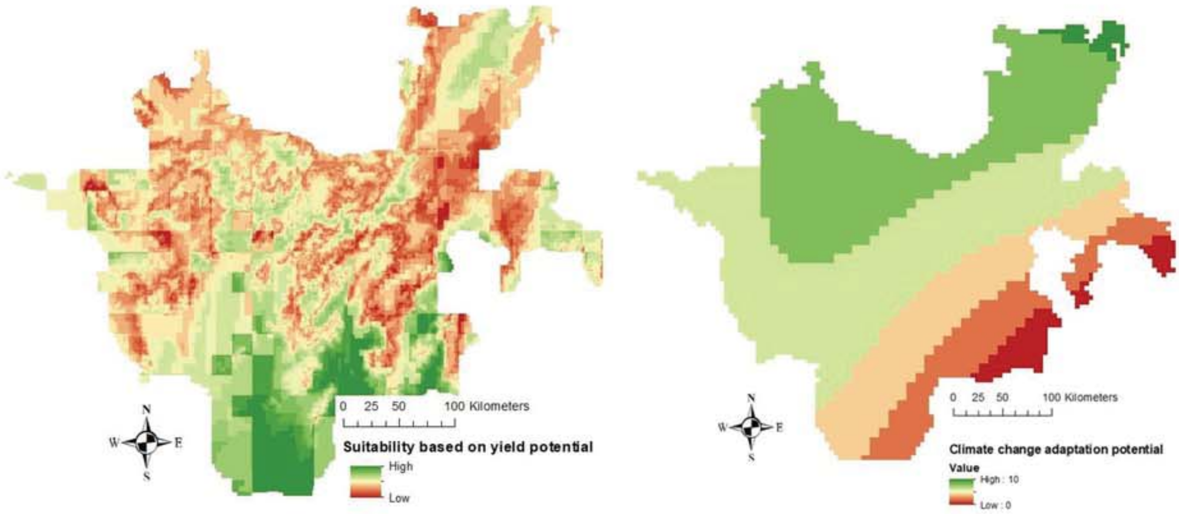
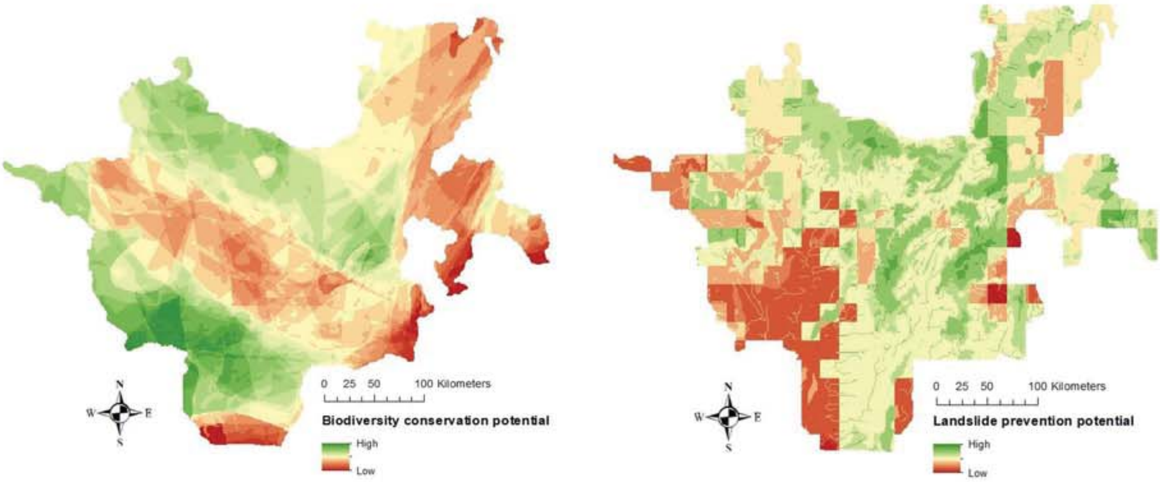


Figure 6.1 illustrates the suitability for shaded coffee certification based on the potential yield loss as shown in Figure 5.1. Areas with low potential yield losses in case of conversion to a shaded system, are more suitable for shaded coffee certification and vice versa. The suitability map displayed in Figure 6.1 roughly indicates that the southern areas of the SNNPR are more suitable for certification and the northern parts less suitable. Figure 6.2 shows the suitability map for certification based on the potential of shaded coffee as a climate change adaptation tool. Areas that are more affected in terms of temperature, are deemed more suitable for coffee certification as shaded systems mitigate crop damages due to climatic changes. The map in Figure 6.2 indicates that the northern parts of the SNNPR are more suitable for certification as temperature changes are highest there. Moving southwards, the area becomes gradually less suitable for certification, according to this map.

Figure 6.3 and 6.4: Suitability map for shaded coffee certification based on the potential to conserve biodiversity (left0 and the potential to prevent landslides (right)



The map shown in Figure 6.3 displays the suitability for certification based on the biodiversity level measured in species richness. The areas that were considered more biodiverse in Figure 5.3 are more suitable for certification as the spatial proximity of a shaded coffee farm is its most important factor in determining its potential to conserve biodiversity. The areas that are the most suitable according to this biodiversity conservation potential are generally in the southwest as well as in the central-northern parts. Noteworthy is that primary forests have not been excluded in this suitability map, whereas this has been done in the MCA analysis. Figure 6.4 shows the suitability for certification according to the potential of shaded coffee plantations to prevent landslides. The areas that had a high landslide risk in Figure 5.4 are considered more suitable for certification. In general, the southwestern parts of the SNNPR are the least suitable according to this map.

Figure 6.5 and 6.6: Suitability map for shaded coffee certification based on the potential to prevent floods (left) and droughts (right)

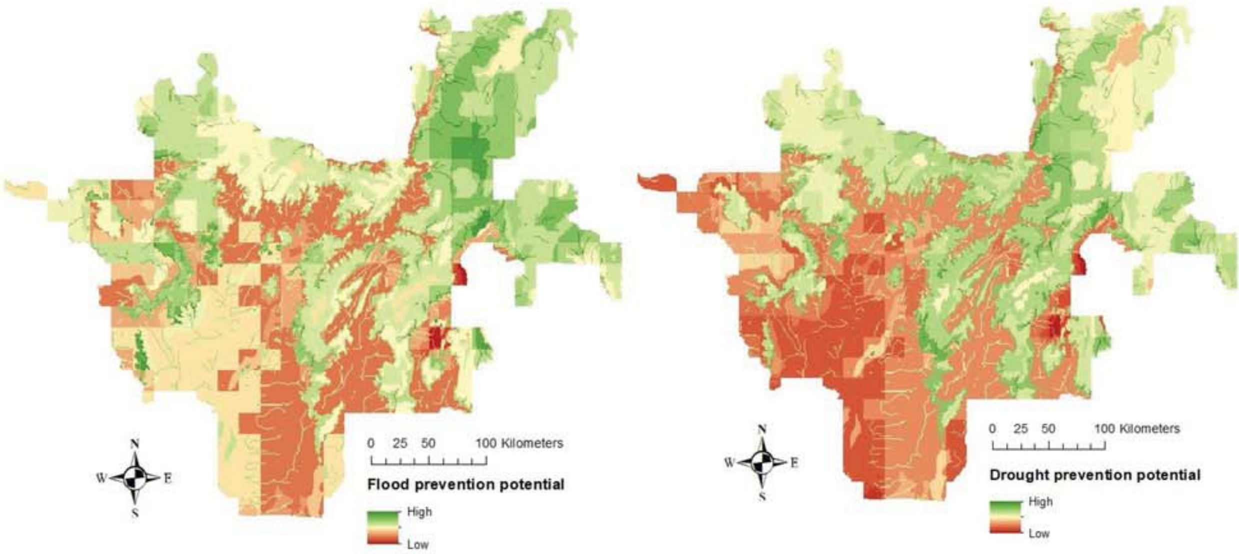
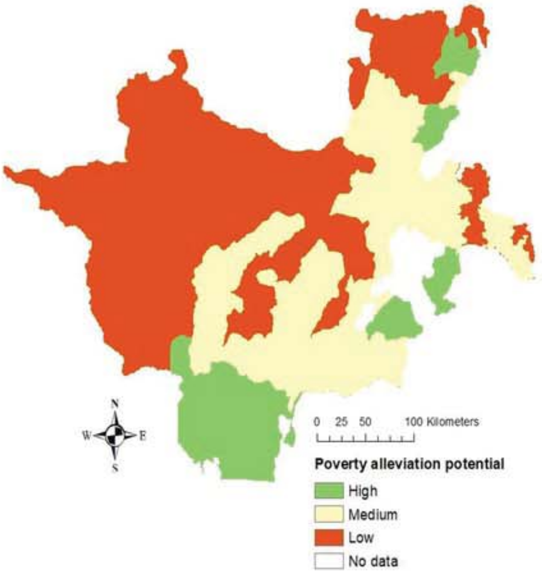
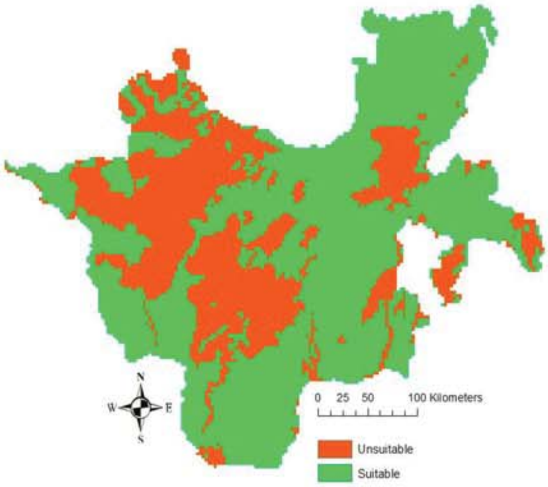


Figure 6.5 presents the suitability map for certification based on the flood prevention potential. Analogous to the landslide risk and the landslide prevention potential, the flood prevention potential is considered higher when there is a higher flood risk. Similar reasoning is used for the drought prevention potential. The suitability map shown in 6.5 indicates that the southern and southwestern areas are the least suitable for certification based on the flood prevention potential. Conversely, the northern and northeastern parts are the most suitable for certification based on this potential. The suitability analysis based on the drought prevention potential resulted in similar results as the southern and southwestern parts were found to be the least suitable. The drought prevention potential lead to more substantial differences in suitability within the SNNPR than the flood prevention potential.

Figure 6.6 and 6.7: Suitability map for shaded coffee certification based on the potential to alleviate poverty (left) and based on land-use type (right).

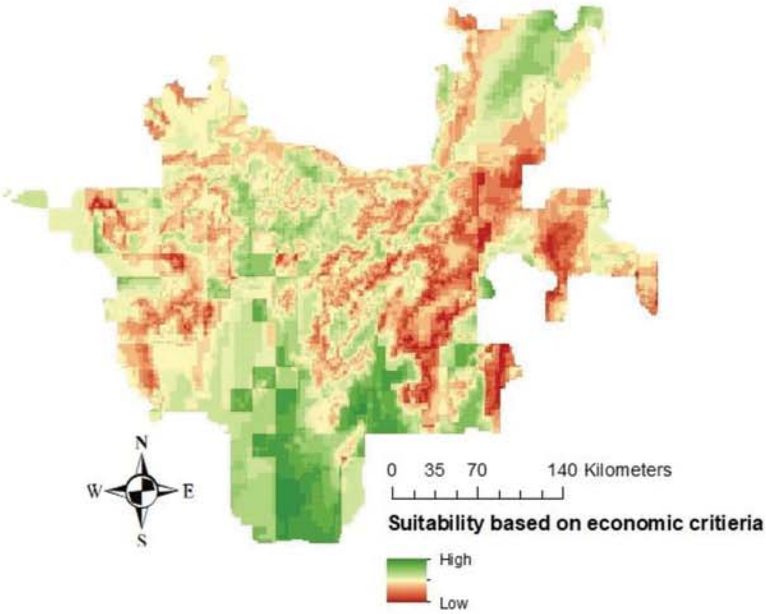




The poverty alleviation potential is considered the highest in areas with higher levels of poverty. Therefore have the different categories in Figure 5.6 been assigned suitability scores increasing with the level of poverty. The area that in 5.6 is indicated with 'minimal' is considered the least suitable for certification and is categorized as 'Low'. Then, the area that is indicated with 'stressed' is considered of medium suitability and is hence categorized as 'Medium'. Finally, the area that is indicated as 'crisis' is considered to have the highest potential for poverty alleviation and is categorized as 'High'. Figure 6.7 shows the suitability map based on land-use type in which data is either classified as 'suitable' and 'unsuitable'. The category 'unsuitable' indicates primary forest and water surfaces and the category 'suitable' indicates all other land-use types.

4.2 Multicriteria-analysis

Figure 7.1 and 7.2: suitability map based on the economic criteria (top) and environmental criteria (bottom)



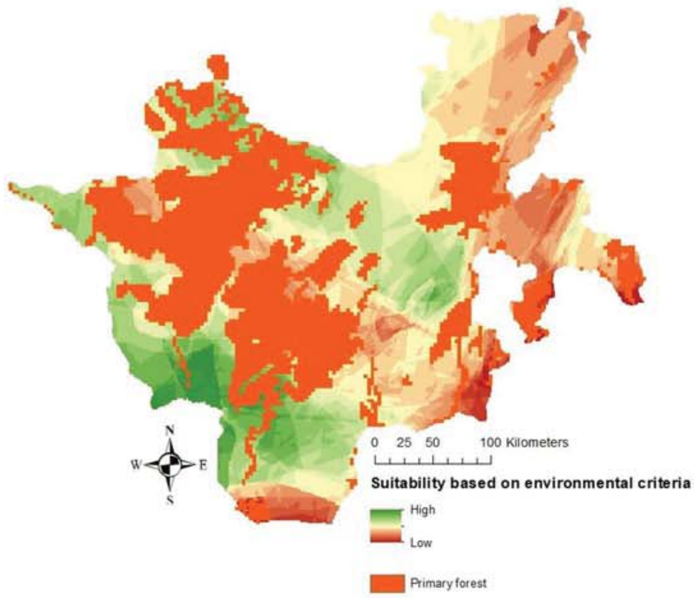
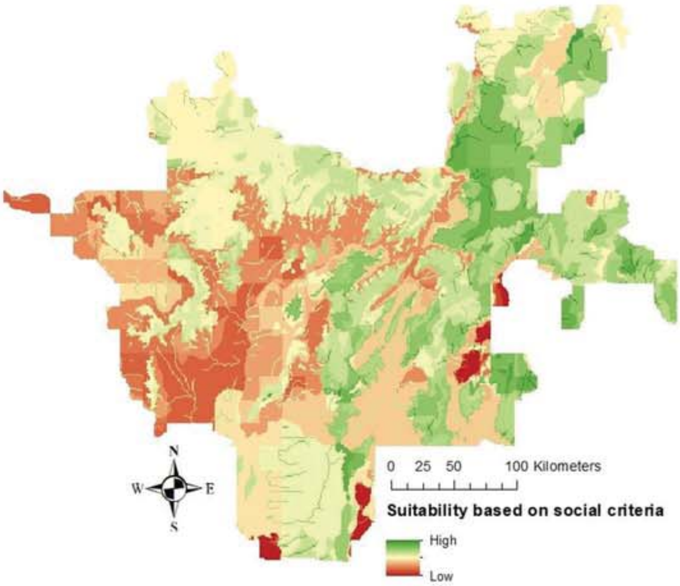


Figure 7.3 and 7.4: suitability map based on social criteria (top) and all three criteria combined according to the weighting in Table 4 (bottom)



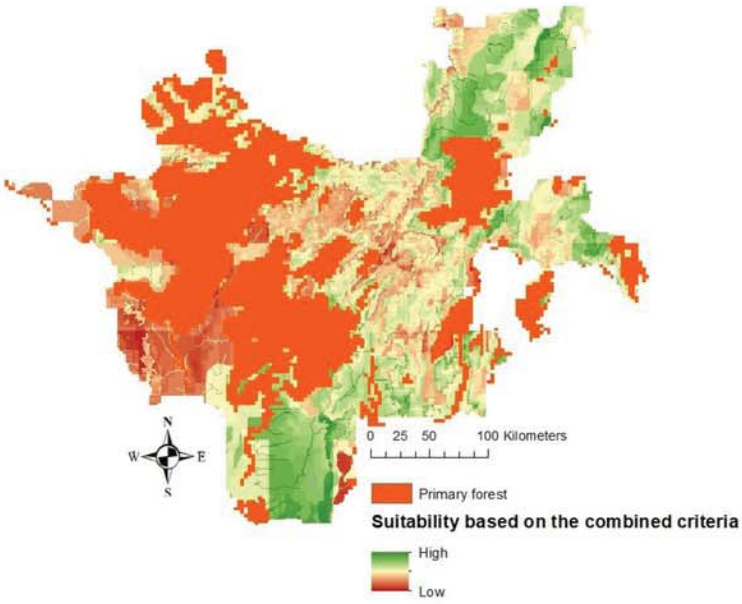


Figure 7 shows the results of the MCA analysis done in this study. The map in Figure 7.1 depicts the suitability for coffee certification according to the economic criteria. In the map, the southern parts of the SNNPR have high suitability scores, whereas the north has low suitability scores. Figure 7.2 indicates the suitability map for certification according to the environmental criteria. The regions marked as orange are primary forest and deemed unsuitable for coffee certification. Taking into account the environmental criteria only, the southwestern areas of the SNNPR are the most suitable for certification. The northeastern areas are the least suitable according to these criteria. Then, the suitability map according to the social criteria is indicated in Figure 7.3. Roughly, this suitability map has high scores for the western parts and low scores for the eastern parts. Finally, Figure 7.4 shows the suitability map with all the criteria combined according to Table 4. Again, the regions marked as orange are considered unsuitable as they are primary forest. The most southern parts as well as the most northern parts of the SNNPR are the most suitable for coffee certification. The western zones of the SNNPR have relatively low suitability scores.

5. Policy implications

Exclusion of primary forests

Both ecosystems and the livelihoods of local communities depend on the presence of forests. Ecosystems depend on forest as it provides the habitat for a variety of species, including species with high conservation status. The livelihoods of local people depend on forest land as forestry provides them with timber, firewood, fruits and honey. Therefore, it seems obvious that certification schemes should exclude primary forests from their schemes to prevent further deforestation. Nevertheless, the opposite is happening as the government is selling large parts of its forests to private investors that use these patches for a variety of crops, including coffee (El Ouaamari & Cochet, 2013). Indeed, in some cases private investors reap the benefits from shaded coffee certification schemes and compete with smallholders that produce shaded coffee. Moreover, as land access to these forests is restricted in case they are sold, local people gain less access to resources, further damaging their livelihoods. Exclusion of the primary forests, that are depicted in red in Figure 8, should therefore be emphasized in setting the standard for certifying coffee as shaded. Important to note is that this exclusion of primary forests goes beyond the government-appointed protected areas as all further deforestation should be countered. Basing a certification system on land-use data instead of administrative protected areas can be considered better for conservation purposes. Reason for this is that the conservation of relatively small patches of forest, that are not included in the protected areas, is important for biodiversity as these patches can serve as 'stepping stones' between large patches of forest and thereby increase habitat connectivity (Asare et al., 2014).

Closing the revenue gap

Another problem with current certification systems is that the price premiums given are insufficient to compensate for the loss of yield when converting to a shaded coffee system (Perfecto et al., 2005). For shaded coffee plantations to be beneficial, a threshold of 70% shade cover needs to be met (Perfecto et al., 2005). However, yields are optimal between a shade cover between 35-65% (Staver et al., 2001). This is due to both ecophysiological constraints as well as the allowance for high-density planting (DaMatta, 2004). Different studies compared the yields of monocultural systems with that of shaded systems with highly variable results. For example, Campanha et al., (2003) found that a monocultural system led to a yield 2443 kg ha–1 and a shaded system led to a yield of 515 kg ha–1 in for 80% shade cover, whereas Jaramillo-

Botero et al. (2010) found yields for monoculture plantations and shaded plantations of 2,646 kg ha and 2,094 kg ha, respectively with 48% shade cover. Reasons of this variability are the large impact of local factors such as temperature, elevation, precipitation and soil condition (Campanha et al., 2003). Nevertheless, studies agree on the negative relationship between yield and shade cover (Campanha et al., 2003; Perfecto et al., 2005; Jarmamillo-Botero et al., (2010). Current certification systems do not base their premium prices on these yield reductions. Rather, current systems base their premium price on market forces and hence consumer demand. As these forces are heavily fluctuating, it is possible for farmers to lose profit by converting to a shaded system. In practice, this leads to the discouraging of farmers to switch to more environmentally friendly practices by making the conversion a high-risk, unattractive investment. Moreover, having market-based premium prices can completely remove the social benefits of certification as farmers receive similar or lesser profits than non-certified farmers in times of low demand (Valkira, 2005). All this leads coffee certification to give no guarantee whatsoever in terms of poverty alleviation.

To counter this problem, premium prices can be calculated via the yield reduction to at least guarantee farmers similar profits as non-certified farmers. To come to a preliminary value of this premium price for shaded coffee in the SNNPR, data was taken from a study done in the Jimma zone by Bote & Struik (2010). The Jimma zone lays within the Oromia region and is adjacent to the northern zones of the SNNPR. This study found yields of shaded coffee and sun-grown coffee of 3100 kg ha -1 and 2130 kg ha–1, respectively. Based on the current coffee price, €1,915 per kg coffee that was derived on August 10, 2019 (Nasdaq, 2019), a farmer would miss out €1857.55 per ha when practicing agroforestry. To compensate for the potential yield loss, a premium price of 45% (€0.87) per kg is necessary. However, as previously mentioned, local factors play a substantial role in the yield reduction. Though using site-specific premium-prices is not realistic at this stage, it is useful to have an understanding of the potential yield losses per area as it allows for the consideration of rough actual costs. Doing so is important as otherwise actual costs may be heavily underestimated, causing farmers to be discouraged to farm shaded coffee. Moreover, it may lead to the underpaying of certified farming which directly contradicts the objective of most certification schemes. Furthermore, it is recommended to encourage shaded systems in areas that are less suitable for sun-grown coffee as shaded coffee systems are more resilient against unfavorable temperatures, natural hazards and soil degradation (Perfecto et al., 2005). Figure 5.1 shows which areas should be prioritized in certification according to this reasoning. The highest losses in potential yield are mainly in the north, whereas the lowest losses in potential yield are in the south of the SNNPR. Therefore, according to this study, it is the least costly to certify shaded coffee in the south.

Prioritizing areas with financial incentives

Multiple studies conclude that paying premium prices by means of certification is not sufficient to counter the ongoing trend of conversion to sun-grown coffee and that schemes must include financial incentives (Philpott & Dietsch, 2003; Perfecto et al., 2005). Whereas premium prices are meant to compensate the farmer for yield losses, financial incentives are bonusses on top of the price premium to incentivize certain behaviors. Taking into account spatial factors in distributing financial incentives can increase the efficiency of these incentives. To maximize biodiversity conservation, it is recommended to prioritize the promotion of shaded coffee along the forest margins to enhance their positive effects on biodiversity. The suitability map derived in this study shown in Figure 7.2 can be used as an indicator of the areas that must be prioritized to meet this objective. To maximize social welfare, it is recommended to prioritize the areas that have the highest risk of the occurrence of natural hazard and to focus on marginalized areas. These areas are pointed out in Figure 7.3.

Carbon offsetting schemes

Without a doubt are certification schemes that take into account yield losses as well as spatial differences within the region more labor intensive and hence more costly to maintain. To be effective, such a scheme requires active promotion of coffee certification in specific areas as well as regular monitoring. These extra labor costs and financial incentives can be compensated for in the price of the shaded coffee at consumer level. However, as Perfecto et al. (2005) points out, a higher consumer price may lead to a decline in the purchasing of shaded coffee. Hence, there is a need for other mechanisms to fund shaded coffee that are more stable throughout time. A promising example of such a mechanism is carbon offsetting. Carbon offsets are reductions in greenhouse gasses or carbon sequestration that compensate for the emission of greenhouse gasses elsewhere (Rahn et al., 2013). Voluntary carbon offsets play an increasingly important role in mitigating greenhouse gases (MacKerron et al., 2009). Particularly, aviation offsets are growing as consumers engaging in flying have increasingly higher willingness to pay for these offsets (MacKerron et al., 2009). Shaded coffee systems can compensate for greenhouse gas emissions elsewhere directly by sequestering carbon as well as preventing further deforestation (Rahn et al., 2013). Average rates of carbon sequestration are around between 50-63 Mg C ha−1 depending on the temperature (Montagnini & Nair, 2004). Agroforestry projects, specifically, are popular among consumers paying for offsetting schemes. As a reason for this, consumers list that they prefer projects that combine carbon sequestration with development strategies. Shaded coffee presents an unrealized potential to be further exploited.

Limitations

This study exhibits limitations in the functions as well as in the data that is used. Firstly, the coffee yield potential can be calculated in a variety of different ways. Though function 1 suffices for the purposes of this study, other factors that are related to the quality of the soil are not taken into account. Moreover, in this study, a negative relationship was assumed between the potential yield and the costs of using a coffee forestry system instead of a monocultural system. While scientific literature confirms this negative relationship, the real costs of having an agroforestry system are highly dependent on coffee prices as well as the demand for shaded coffee. As these prices and demands are highly fluctuating, this has not been accounted for. Secondly, the climate change adaptation potential is based on only one climate model (INMCM4.0) and one representative concentration pathway (8.5). Both the model itself and the chosen representative concentration pathway include uncertainty. This has been reflected in this study by giving the criteria a relatively low weight. However, as the implications of climate change on Ethiopian coffee production are serious (Jaramillo et al., 2011), this criteria may have been undervalued in importance due to the uncertainty involved. Furthermore, the relationship between yield and shade cover is not fully understood. While studies agree upon a negative relationship, local factors are thought to have substantial impacts on the difference in yield. To gain more insight into how this relationship unfolds in the SNNPR, on-site data-collection is required.

6. Conclusion

Replacing the one-size-fits-all approach in coffee certification is costly but necessary for NGOs to meet their objectives. Current certification systems are unsuccessful in alleviating poverty and preserving biodiversity due to their failure to consider spatial factors that influence the true costs and benefits of shaded coffee systems. Moreover, current certification systems fail to uphold high standards and sufficiently frequent monitoring. This study proposes to improve the certification system by introducing GIS-based multicriteria analysis based on the following criteria: yield potential, climate change impact, biodiversity level, land use type, landslide risk, flood risk, drought risk and poverty level. This data can be used to improve certification systems in three different ways. Firstly, maps including land use data can be used to exclude primary forests from certification to prevent further deforestation. Secondly, revenue gaps are highly dependent on spatial factors. Having a rough idea about the potential yield losses supports a system that gives out fair premium prices to certified farmers. Finally, financial incentives are important in encouraging shaded coffee farms to meet environmental and social objectives. Suitability maps as derived in this study can help prioritizing important areas for conservation and improving livelihoods of local people for more effective certification. Furthermore, alternative ways of funding such as carbon offsetting can act as a promising tool to finance certification systems. Taking into account spatial factors in coffee certification paves way for a more environmentally- and people-friendly system.

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