Chapter 4

Village Stratification for Policy Analysis: Multiple Development Domains in the Ethiopian Highlands of Tigray

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Many countries in Sub-Saharan Africa suffer from problems related to poverty, natural resource degradation, and the complex interactions between these phenomena (Cleaver and Schreiber 1994). In the northern Ethiopian highlands of Tigray region, problems of poverty and degradation are extremely severe: population density is very high, rainfall is scarce and erratic, and soil fertility is low. Under such conditions, farmers need to rely on external inputs and soil conservation practices in order to stabilize or increase yields. Within the current land use pattern, a wide range of different options are available for intensification of production systems. The selection of appropriate pathways for intensification may be different for specific locations. Therefore, village stratification can be used to select technologies and practices that are applied under particular agro-ecological, socio-economic, and institutional conditions.

The concept of development domains is used to facilitate the targeting of development interventions. As discussed in Chapter 2, major dimensions of development domains include the agricultural resource potential, market access, and population density. These aspects may distinguish between situations where Malthusian or Boserupian development is likely to take place (Pender 1998). Areas with high population density, low agricultural potential, and low market access can be expected to follow a Malthusian development path, where land resources typically suffer from soil mining and resource degradation. Boserupian development tends to occur when there is sufficient market access that enables specialization, leading to a more efficient use of scarce resources, as illustrated in the study *More People—Less Erosion* (Tiffen, Mortimore, and Gichuki 1994). In these settings, the proximity of markets allows the adoption of more sustainable agricultural practices. However, in many parts of Africa, soils are so poor that the maximum carrying capacity is reached at rather low population densities (Kruseman 2000).

The identification of development potentials is often addressed in an anecdotal fashion, whereas quantitative analysis is required for identifying more precisely the possibilities for targeting of interventions. This implies a search for an accurate definition of the critical dimensions that broadly determine different strategic development options. Following Pender, Place, and Ehui (1999), the dimensions we use for distinguishing among development domains are (1) agricultural potential (i.e., biophysical environment), (2) population density, and (3) market access (i.e., socioeconomic environment). These dimensions are largely exogenous to the households that try to cope with the biophysical and socioeconomic environment. Household decisions regarding land use practices and production technologies result in particular livelihood strategies. We can differentiate with the three criteria a total of eight different situations. We discuss each of these settings and identify their importance for the selection of typical land use practices.

Identification and quantification of development domains has an important practical meaning. It offers a framework for the design of particular development interventions that are appropriate for certain areas. Village stratification is considered useful in order to identify the structural factors that influence the choice of certain livelihood strategies. When diversity among villages is more important than heterogeneity among households in the same village, targeting can be safely done at the community level (Bigman and Fofack 2000).

Geographic targeting can also be interesting when patterns of heterogeneity within villages are comparable regarding the presence of better- and poorly endowed households, female-headed households, and landlessness. This is broadly the case in Tigray region, where a common cultural, ethnic, and political background provides a shared legacy that results in relative socioeconomic homogeneity among the population.[1] If household resources are relatively homogeneous, the key dimensions we mentioned before (i.e., agricultural potential, population density, and market access) primarily define the development domains. Poverty and productivity in a broad sense are directly linked to such geographic considerations, even if there remains some heterogeneity among households within villages. Differences between villages tend to be more appealing because what constitutes a rich farmer in one village may be considered a poor one in another village. These differences are mainly explained by the development domain dimensions. Geographic targeting can then be considered an effective strategy for selectively enhancing a process of agricultural intensification.

In this chapter we develop a generic methodology for stratifying villages into development domains using multivariate analysis of data derived from a community survey. We determine the relative importance of the critical dimensions of the development domains for particular livelihood strategies. The degree of correspondence between these aspects indicates to what extent geographic targeting is justified. The results of the analysis confirm the close correspondence between development domains and resource use practices.

The remainder of this chapter is structured as follows. In the next section the concept of development domains is discussed within the context of the Ethiopian highlands of Tigray. Next, we outline the methodology used for deriving the main dimensions of the development domains. Hereafter, we discuss the relevance of these development domains for crop choice and land use practices in Tigray. We conclude with some implications for the targeting of development interventions.

Development Domains in Tigray

The northern Ethiopian highlands of Tigray face serious problems related to high population density and limited agro-ecological potential. Regional programs for soil and water conservation have been launched that are intended to increase land and labor productivity. However, given the modest public resources that are available, choices have to be made about where to target specific activities. Not all activities are suitable for each community, and different communities are likely to benefit most from specific types of interventions. Under these conditions, we cannot rely on a "one-size-fits-all" strategy, and specific criteria must be developed in order to differentiate among *kushets* (communities) and to select the most appropriate development strategies.[2]

The concept of development domains can be used to identify the critical dimensions that influence the adoption of certain resource management practices (Hagos, Pender, and Gebreselassie 1999; Pender, Place, and Ehui 1999).[3] This approach is based on the notion that it is possible to disentangle the core elements of past local development strategies in terms of adopted technologies. These can be used as a first step to analyze what selective array of technologies or services might be offered to potentially benefit other communities with similar development domain dimensions. Patterns of cropping and livestock activities per se do not indicate successful local development strategies, nor do they represent less-than-preferable outcomes. The successful adoption of technology, however, is an indicator of potential development pathways.

One of the main hypotheses of the development domains concept is the existence of differences in comparative advantages for adopting alternative livelihood strategies, giving rise to essentially different development pathways. These differences in comparative advantage can be attributed to three main factors: agricultural potential, market access, and population pressure.

Agricultural potential is a complex aggregate of various biophysical and agroclimatic factors that can be decomposed in a number of different underlying factors, including rainfall, soil type and quality, altitude, slope, topography, and the presence of pests and diseases. These aspects are, to a large extent, exogenous to the farm households but are of overriding importance for determining the comparative advantage of producing different types of agricultural commodities in a specific setting. The role of the agricultural potential varies for different commodities and over time as a result of human-induced (e.g., soil degradation) and exogenous change (e.g., climate change). The multidimensional aspect of agricultural potential, especially the fact that it can change over time, should be taken into account in developing medium- and long-term strategies. Taking a cross section of a larger region that captures to some extent different stages of human-induced and exogenous change makes the use of a comparative static approach acceptable in the absence of a long time series of relevant data.

Market access is equally important for determining the comparative advantage of a specific locality for producing certain tradable commodities. Market access also involves various dimensions and encompasses such components as distance to roads, quality of roads, travel time, distance to markets and urban centers, degree of competition, information costs, and transport opportunities. Although many factors play a role, travel time is usually considered most crucial for market exchange and input purchase decisions. Travel time is the result of some of the previously mentioned variables (e.g., distance, quality of roads, and transport opportunities) and determines others (information costs). It is therefore important to define a measurable proxy for this factor. Market access is closely linked to the concept of transaction costs whereby the penalty related to lack of market access influences farm household decisions related to consumption and production (Omamo 1998; Goetz 1992).

Population pressure has long been acknowledged as being a major driving force with respect to the labor intensity of agriculture, creating a conducive environment for innovations in technology, institutions, markets, and infrastructure (Boserup 1965; Ruthenberg 1980; Hayami and Ruttan 1985; Binswanger and McIntire 1987). It refers to both the density of population and the local available purchasing power. Population pressure affects labor utilization decisions and hence agricultural management practices as well as the return to different types of investments.

These three main factors obviously interact with each other in complex ways. In general, population pressure tends to be higher in areas with a greater agricultural potential and with better market access or both, allowing the existing population to make a decent living while encouraging immigration from less favored areas. On the other hand, increased population pressure is considered a major contributing factor to the severe land degradation found in many parts of Africa, thus affecting the agricultural potential. Market access tends to be better in highly populated areas, where the per capita costs of infrastructure investment are lower. Availability of infrastructure also tends to be better in high-agricultural-potential areas that guarantee higher returns to investment. In their seminal study Machakos, Tiffen, Mortimore, and Gichuki (1994) made a case for increased population pressure leading to less soil degradation. In this specific case, better market access permitted the necessary investments to reverse the process of soil degradation, allowing alternative employment outside agriculture to reduce population pressure. The absence of such market outlets in other parts of eastern Africa has led to accelerated degradation. In Tigray, off-farm employment opportunities are limited primarily to food-for-work and food-for-cash schemes of public goods provision. In areas with low population density and limited agricultural potential where market access is constrained, small demographic changes can occasion a chain of events leading to degradation beyond the point of no return, as illustrated by the case of the Mossi plateau in Burkina Faso (Savenije and van Zutphen 1991).

In summary, the variables of market access and population pressure are very often correlated at the local level. Increasing population pressure may lead to better market access, and improved market access tends to attract immigration and hence increasing population pressure. Similarly, agricultural potential may be related to population pressure, but this relationship is easily offset under conditions of scarcity of market infrastructure.

In the northern Ethiopian highlands of Tigray we can identify settings with high and low population density in both remote and accessible regions. In addition, there is no clear correspondence between population density and the available agro-ecological potential. This is largely because population movements were originally induced by health considerations (escaping from malaria incidence in the lowlands) and in later stages by political factors (moving away from conflict areas). Tenure policies assigning land according to household size and family needs further reinforced relatively equal factor distribution at the village level. In addition, recurrent droughts in the early 1970s and mid-1980s led to a general process of asset loss and destitution that affected both poor and better-off households (Devereux, Sharp, and Amare 2004). Finally, during the two decades of military conflict, farm investment decisions were seriously affected.

Methods and Data

In order to develop a spatial classification of different village-level development domains for the northern Ethiopian highlands of Tigray, a statistically robust methodology is required. We used multivariate statistical techniques to identify critical development dimensions and their implications for crop choice and land use practices. Therefore, we perform an analysis in three stages, addressing the following issues:

- Identification of the main dimensions of village development domains

- Analysis of the mutual independence of the development domain dimensions, in order to adequately distinguish what kind of interventions might be useful

- Identification of the linkages between the development domain dimensions and selected land use and cropping practices

The methods used in this chapter rely on the availability of a village level survey conducted by IFPRI, ILRI, and Mekelle University in 1998 and 1999.[4] The goal of this survey was to capture main characteristics of the villages in terms of physical and social infrastructure, predominant economic activities, and development indicators. We used this survey to classify each village (*kushet*) in the region into a three-dimensional matrix of factors influencing development potential. At the same time, predominant production systems and livelihood strategies were derived from the same survey, giving an indication of the selected development strategies in these particular settings.

The development domains are differentiated according to three key factors: agro-ecological potential, market access, and population density. Major factors contributing to agricultural potential are rainfall, altitude, and initial soil quality. The community-level survey also provides data with respect to altitude and both quantitative and qualitative measures of soil quality.[5] Rainfall data from other sources were combined with the community survey. The factor *market access* is measured in terms of distances and walking times to roads, services, towns, and market outlets. The factor *population density* is directly derived from survey data.

For each of these dimensions there are usually a number of different variables available. Choosing the useful proxy variables is not always easy. Especially in the case of agricultural potential, which by definition includes multiple dimensions, we should be careful to avoid arbitrariness. We relied on factor analysis methods to reduce the data, deriving single quantitative measures for each main factor. This has the advantage of using all the variables in the data set that are relevant to the analysis while preventing the occurrence of dependency among the factors used to define development domain dimensions. Because we are not able a priori to determine whether the development domain dimensions are completely independent, we test for this using a two-stage least-squares and seemingly unrelated regression.

Once we quantified the development dimensions, we performed a detailed analysis of the effects of these variables on the choice of particular land use systems and cropping practices. This provides insight into the determinants of different livelihood strategies and development opportunities within the communities.[6] This analysis is based on regressing the development domain dimensions with variables related to land use (i.e., crop choice, livestock) and related production technologies (i.e., fertilizer use, animal feeding regimens, soil conservation practices). In addition, we analyze the impact of the development domains on credit use and some welfare indicators (housing, education). The latter variables represent the outcomes of the current development pathways for the communities in Tigray and are likely to depend to some degree on the development domain dimensions.

Once we have determined the relative importance of the development domain dimensions, we are able to stratify the villages in the survey. Instead of using cluster analysis to categorize households into quasi-arbitrary groups, we opt for a more structural approach to identify the extremes using the available dimensions. For this purpose, we divide the villages into three groups for each dimension depending on whether they have a high, low, or intermediate score on each dimension. We prefer this procedure because development domain dimensions in general tend to present themselves on a sliding scale.

Identifying Development Domains

This section presents the results from the village-level analysis of critical development domains and compares these to the hypothetical development opportunities (as identified by other authors, including Hagos, Pender, and Gebreselassie 1999). Population density is directly captured by the corresponding variable in the community survey.[7] With respect to agricultural potential, we differentiate between soil quality and rainfall or altitude. For soil quality, two different dimensions are distinguished that explain 60 percent of the variation (see Table 4.1).[8] The explanatory variables include proportions of different quality classes of cultivated and grazing land. Factor analysis results for defining agricultural potential indicate the importance of land degradation and soil quality (see Table 4.1).

Other components of the agricultural potential dimension are elevation and precipitation.[9] By combining these factors into the factor analysis, normalized

Table 4.1 Factor analysis results for soil quality in agricultural potential

	Factor loadings	
Variable	**Level of degradation**	**Soil quality**
Proportion of severely eroded cultivated land	0.822	0.103
Proportion of moderately eroded cultivated land	0.578	0.461
Proportion of severely eroded grazing land	0.779	–0.03
Proportion of moderately eroded grazing land	0.863	–0.07
Proportion of good soil	–0.303	0.882
Percentage of variance loaded onto the factor (extraction sums of squared loadings)	49.04	20.14

Note: Extraction method: principal-component analysis.

values can be obtained (see Table 4.2). Note that data on elevation were obtained from two different sources.[10]

Market access is divided into two separate factors. The first factor relates to physical distance from markets and infrastructure (see Table 4.3), and the second relates to the presence of external institutions that facilitate market access (see Table 4.4).[11] Table 4.3 shows that remote villages have a consistently high score on all distance variables.

Table 4.4 shows the importance of the presence of local institutions. The first factor represents the local water associations in charge of the promotion of irrigation and the distribution of water. The second factor loads the presence of cooperatives and indicates that there is a negative correlation between the presence of cooperatives and the availability of credit by other agencies (NGOs and state Bureau of Agriculture). The third factor loads the activities of the Bureau of Agriculture, delivering credit and actively involved in the promotion of improved crop

Table 4.2 Factor analysis results for rainfall and altitude in agricultural potential

	Factor loadings	
Variable	**Elevation**	**Rainfall**
Expected annual precipitation (millimeters)	0.053	0.997
Elevation (meters above sea level)	0.989	–0.010
Lower bound on altitude (meters above sea level)	0.937	–0.115
Upper bound on altitude (meters above sea level)	0.901	0.048
Mean altitude (meters above sea level)	0.980	0.023
Percentage of variance loaded onto the factor (extraction sums of squared loadings)	72.65	20.21

Note: Extraction method: principal-component analysis.

Table 4.3 Factor analysis results for market access (distance)

Variable	Factor loading Market access
Walking time to market center (minutes)	0.932
Walking time to bus service (minutes)	0.876
Walking time to all-weather road (minutes)	0.919
Distance to town (kilometers)	0.875
Distance to all-weather road (kilometers)	0.881
Percentage of variance loaded on factors (extraction sums of squared loadings)	80.44

Note: Extraction method: principal-component analysis.

and livestock practices. The fourth factor loads the delivery of credit by the NGO Relief Society of Tigray (REST) in areas where commercial credit (traders and moneylenders) do not have a strong presence.

Testing for Independence of Development Domain Dimensions

The interesting element in this analysis is that it is not clear a priori whether these factors are endogenous or exogenous. It could be the case, for instance, that institutional presence is the result of some of the other dimensions in development domains. We therefore need to test for the independence of these aspects.

Summarizing the factors determining development domains, we included the following factors for the agricultural potential: precipitation (*RF*); two variables

Table 4.4 Factor analysis results for market access (institutions)

Factor	Irrigation institutions	Cooperatives	Bureau of Agriculture	NGOs (REST)
Market cooperative	0.37	0.65	0.21	0.00
Consumer cooperative	0.37	0.77	–0.08	0.05
Water association	–0.71	0.39	0.31	0.15
Credit by REST	0.35	–0.03	–0.34	0.64
Credit by Bureau of Agriculture	0.22	–0.47	0.70	0.06
Irrigation promoted	–0.75	0.24	0.26	0.23
Livestock improvement promoted	0.41	0.00	0.61	0.45
Commercial credit	0.26	0.18	0.33	–0.61
Percentage of variance loaded on factors (extraction sums of squared loadings)	21.8	18.6	16.3	13.2

Note: Extraction method: principal-component analysis, variables all of yes/no type.

defining soil properties, soil quality (*SQ*) and degradation level (*DL*); and elevation (*EL*). Population density (*PD*) and market access (*MK*) are captured in single variables. We can test for independence or linkages among these factors through the following system of equations:[12]

$$DL = f(SQ, RF, PD, MK) \quad (4.1)$$

when the inherent soil quality, rainfall, market access, and population density may influence degradation level.

$$PD = f(DL, SQ, RF, EL, MK) \quad (4.2)$$

where population density may be caused by a variety of factors relating to other biophysical or institutional factors determining development domains.

$$MK = f(SQ, RF, EL, PD) \quad (4.3)$$

where market access may be related to biophysical factors and to geographic location.

For each of the institutional factors (IF_i) we test,

$$IF = f(SQ, DL, PD, MK, EL) \quad (4.4)$$

Results of the independence tests indicate that in this system of equations the independent variables are almost completely independent, so they are not likely to be endogenously determined.[13] The variables that are not endogenously determined are inherent soil quality, elevation, and rainfall. Degradation level is only slightly correlated with rainfall; population density with inherent soil quality, elevation, and rainfall; and market access is correlated with elevation. This poses no major problems for the subsequent analysis because there is no endogenous determination. In the case of institutional factors, a minor problem with endogeneity emerged because some of the factors depend on population density and market access in addition to being slightly correlated to exogenous factors. This implies that to be on the safe side, we need to use three staged least-squares to determine which right-hand-side variables should be used in the equations. Arguably, equations (4.1)–(4.4) might contain some omitted variables because factors pertaining to development domain dimensions include only a limited number of underlying variables as a result of data availability. We consider, however, that the model captures the major development domain dimensions as indicated by theoretical considerations regarding rural development.

Village Stratification

For a further analysis of the village development domains we can now use the following six dimensions: market access, population density, and four aspects related to the agricultural potential—altitude, rainfall, soil quality, and degree of degradation. Stratifying the communities according to the specific development domains is used to identify different homogeneous settings. In the graphs of Figures 4.1–4.3, the villages are plotted according to the main development dimensions.

From Figure 4.1 we notice important differences in market access and population density among the villages. The diversity in these dimensions is wide, and situations with high and low population density occur in both well-endowed and poorly endowed villages.

Figure 4.2 depicts the data concerning altitude and rainfall. It illustrates basically three different situations: villages with low altitude and high rainfall, villages with high altitude and low rainfall, and only a few cases with high altitude and high rainfall. Variability in rainfall is, however, only between 475 millimeters and 770 millimeters per annum, whereas altitudes range from 1,500 to more than 3,000 meters above sea level. Scarcity of rainfall in this area generally represents a major limiting factor for arable cropping.

Figure 4.3 indicates a rather even distribution of soil quality and degradation over the communities. Soil degradation occurs both in villages with good soil quality

Figure 4.1 Development domain dimensions: Population density and market access

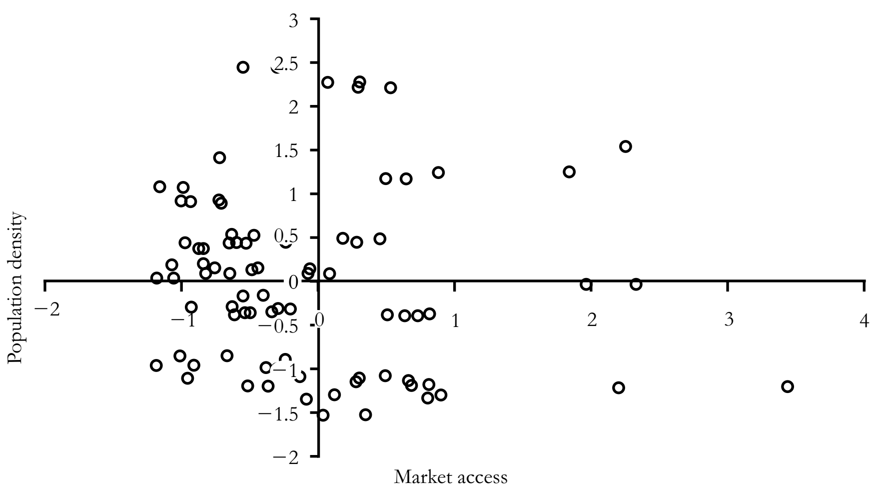
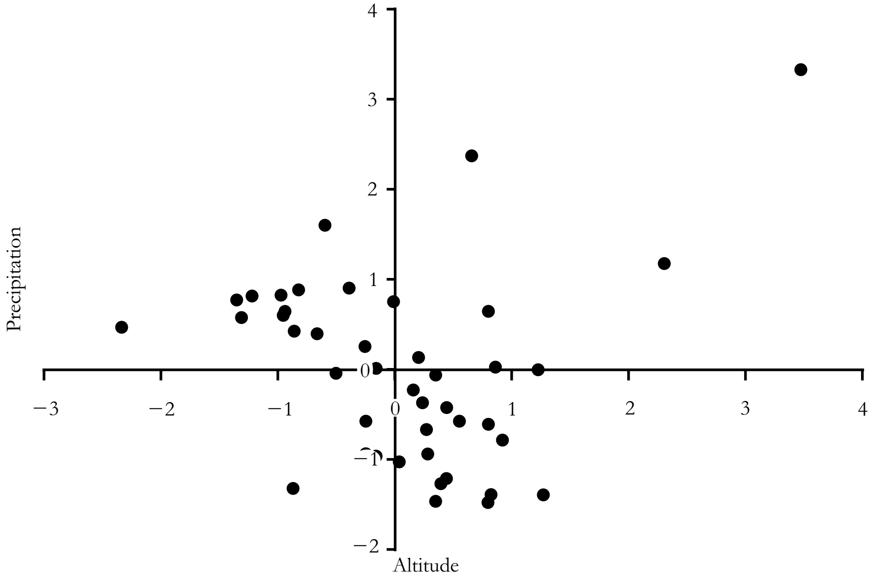


Figure 4.2 Development domain dimensions: Altitude and precipitation



and in villages with poor soils. However, the impact of degradation is substantially stronger in settings characterized by low intrinsic soil quality.

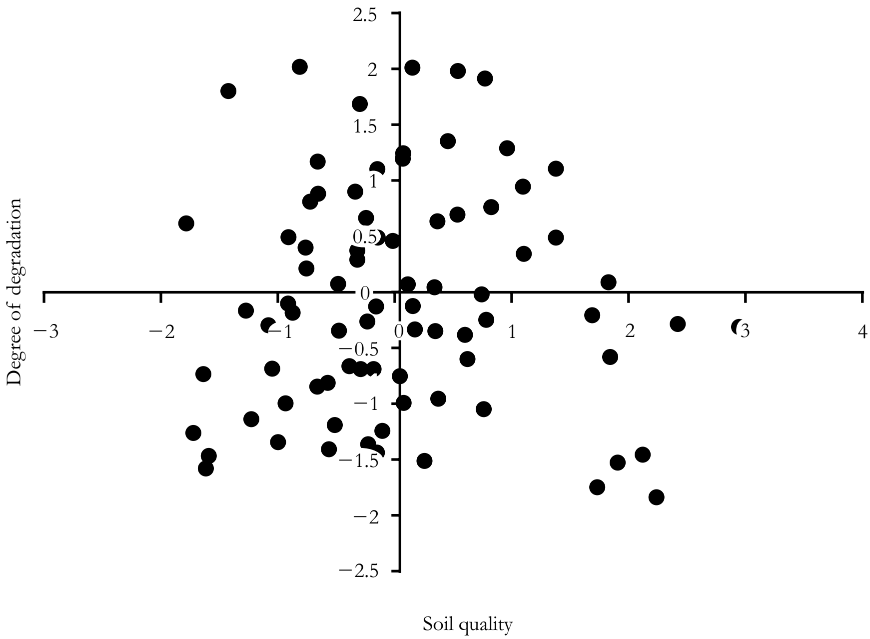
When we combine all the information available from 45 villages, the sample can be classified into eight different development domains (see Table 4.5). We used the factor scores on the three dimensions discussed before and excluded the data ranges close to zero. In the case of agricultural potential we used a weighted average of rainfall, soil quality, and degree of degradation to determine overall potential.[14]

The communities in the area are distributed fairly evenly over high- and low-altitude areas, except that the communities with low market access, high population density, and low agricultural potential are concentrated in the high-altitude areas.[15] This diversity implies that farmers exhibit different choices or preferences regarding suitable land use practices and market orientation that are most appropriate to their local conditions.

Land Use Patterns and Production Systems

We analyze the importance of different critical dimensions of the village development domains in order to identify the most important elements for the corresponding development pathways. Therefore, we examine the influence of the exogenous

Figure 4.3 Development domain dimensions: Soil quality and degree of degradation



indicators of agro-ecological potential (population density, distance to markets, and access to institutions) for the resource management strategies. The latter strategies represent choice variables at the level of farm households.

We can distinguish three specific domains of household decisionmaking. First, strategies for land use are discussed, focusing on cropping and livestock activities. Crop choice is expected to depend mostly on differences in agricultural potential but

Table 4.5 Village stratification

Market access	Population density	Agricultural potential: Low	Agricultural potential: High
Low	Low	6	6
	High	4	3
High	Low	6	4
	High	7	9

Note: $N = 45$.

is also influenced by market access and population density. These factors together determine the comparative advantage for the agricultural production activities. Livestock activities involve long-term investments for the purchase and maintenance of animal numbers and require the availability of pastures and institutional support. The second aspect we explore refers to technology choice. The selection of appropriate cropping and livestock management regimes tends to be influenced by land and labor resource endowments, market outlets, and institutional support. Given the importance of rural financial services for the adjustment of land use practices, we explicitly discuss the determinants of credit use.[16] Finally, we discuss a number of social development indicators in Tigray region that reflect differences in welfare.

The data analysis is focused on the relationship between the structural village dimensions and the land use and production systems that reflect specific livelihood strategies. The dimensions of development domains are considered to be indicators for the possibility of relying on a certain development pathway. We used three-stage least-squares (3SLS)[17] to estimate the relationship between the endogenous and exogenous variables. Endogenous variables are variables such as activity and technology choice that form part of predominant livelihood strategies. Exogenous variables are the development domain dimensions and institutional dimensions. Only those factors related to livelihood strategies and development pathways with an adjusted R^2 higher than 5 percent are included to avoid spurious correlation.[18]

Activity Choice

The community survey data provide information on the proportions of arable cropping activities within agricultural systems. This can be considered as the aggregate outcome of individual choices at village level. Main cereal crops in the area are barley, *teff,* maize, wheat, sorghum, and finger millet. The selection of cereal crops strongly depends on the agro-ecological conditions, especially rainfall. In addition, some pulses are grown, including chick peas, fava beans, and field peas. To a very small extent cash crops are grown, such as flax, sunflower, sesame, and haricot beans. The single-year production pattern masks to some extent the occurrence of crop rotations, but intercropping appears in the overall land use pattern.[19] Livestock activities are particularly important for the highland communities, but not all households are equally involved. The survey indicates that about 25 percent of the households have no oxen, 40 percent possess only one ox, 25 percent possess two oxen, and 10 percent have more than two oxen. The distribution of livestock indicates that there are marked differences within communities with respect to livestock holdings.

The factors pertaining to elevation and rainfall are most important in determining cropping patterns (see Table 4.6). This confirms the key importance of

Table 4.6 Relation between crop choice and development domain dimensions using three-stage least-squares

Dimension	Barley	Maize	Wheat	Sorghum	*Teff*	Niger seed	Chickpea	Fava beans	Lentils	Field peas	Doliches	Haricot beans
Constant	0.2119***	0.1276***	0.1060***	0.0972***	0.2024***	0.0079***	0.0269***	0.0446***	0.0181***	0.0235***	0.0025***	0.0113***
Soil degradation	–0.0411***	–0.0036	–0.0182*	–0.0083	0.0376**	0.0027	–0.0066	–0.0079	–0.0012	–0.0010	–0.0009	0.0026
Soil quality	0.0006	0.0283**	–0.0135	0.0181	–0.0131	–0.0006	–0.0005	–0.0025	–0.0009	0.0097	0.0005	–0.0030
Elevation	0.1491***	–0.0209	0.0623***	–0.0641***	–0.0909***	–0.0044**	–0.0084*	0.0499***	0.0186***	0.0132*	0.0076***	–0.0070*
Rainfall	–0.0895***	0.0696***	–0.0386***	0.0435***	0.0662***	0.0036**	0.0097**	0.0196**	0.0061*	0.0057	0.0033***	0.0031
Population density	–0.0441***	–0.0303**	0.0163	–0.0156	0.0326*	0.0031*	0.0083*	0.0061	0.0010	0.0078	–0.0033***	–0.0058
Distance to markets	0.0093	0.0164	0.0038	0.0398**	–0.0544***	–0.0008	–0.0020	0.0039	0.0062	0.0022	0.0009	0.0061
Cooperatives	–0.0372**	0.0316**	0.0140	–0.0164	0.0346*	0.0002	0.0042	–0.0083	–0.0041	0.0072	0.0010	0.0017
NGO credit	0.0087	0.0480***	–0.0135	–0.0081	–0.0009	–0.0003	0.0012	0.0110	–0.0010	0.0057	0.0020	–0.0037
Irrigation institutions	0.0303**	0.0137	–0.0009	0.0107	–0.0332*	0.0010	–0.0002	0.0136	0.0025	–0.0035	0.0021*	0.0000
Adjusted R^2	0.5364	0.3172	0.3935	0.3532	0.2808	0.0477	0.0567	0.2693	0.2326	0.0895	0.4027	0.1492

Note: Dependent variable is proportion of farm households growing a specific crop.

***, **, *** mean coefficient is statistically significant at 10 percent, 5 percent, and 1 percent level, respectively.**

rainfall and altitude (temperature) as major limiting factors for crop production in Tigray, whereas intrinsic soil fertility only plays a secondary role (except for maize). Wheat and barley are both grown in high-elevation areas with low rainfall. Given its lower labor demands, barley tends to be grown in less-populated areas where there are no cooperatives and there is a presence of irrigation institutions. The cereals cultivated in the higher-rainfall areas (maize, sorghum,[20] *teff*) show differences with respect to soil quality requirements. *Teff* production is found in areas with a high degree of land degradation, whereas maize is selected in areas where better soils are more prevalent. In addition, *teff* is cultivated in areas with better market access, and sorghum is found in more remote villages. Maize cultivation is favored by the presence of cooperatives and NGOs that guarantee input provision and technical support.[21] Likewise, *teff* cultivation is positively correlated with the presence of cooperatives, but this crop is replaced by higher-value horticulture crops when irrigation institutions are active. With respect to pulses and other diversification crops, the factors *elevation* and *rainfall* are of major importance. Doliches is grown in low-population-density areas where irrigation institutions are present, whereas chickpeas and niger seed are found in higher-density population areas.

The factor *rainfall* is also influencing livestock strategies in the area (see Table 4.7). More rainfall, better soils, and lower population density are positively related to ox availability, indicating that both the quality and the quantity of resource endowments are relevant for ox acquisition. Market access and cooperative presence tend to favor the proportion of farmers with more than two oxen, who usually operate more input-intensive and commercially oriented farming systems. Cows are found in remote areas with less degraded soils, sheep are maintained in settings with low population density and high elevation, whereas goats are located in villages with the opposite characteristics. Beekeeping is located in remote but highly populated areas.[22] The effect of the livestock promotion programs by the Bureau of Agriculture (BoA) is clearly noticed in the growing proportion of households with two oxen but is inversely related to goatkeeping. It is also clear that the involvement of local NGOs in livestock promotion is rather minimal.

Technology Choice

In Tigray region, a wide range of different land use technologies have been promoted and adopted by rural households. Table 4.8 provides an overview of the proportion of farmers who make use of external inputs (i.e., fertilizers, seed), rely on improved land use practices, and made fixed investment for soil conservation, pasture development, or anti-erosion works. Intercropping and crop rotation, agroforestry, and terracing are adopted by more than half of the farmers, but irrigation is limited to some selected locations. Fertility-enhancing practices such as green

Table 4.7 Relationship between livestock ownership and development domain dimensions

Dimension	No oxen	One ox	Two oxen	More than two oxen	Cows	Sheep	Goats	Beehives
Constant	0.2411***	0.4291***	0.2461***	0.0946***	0.3888***	0.2987***	0.2860***	0.1749***
Soil degradation	0.0094	–0.0046	–0.0012	–0.0028	–0.0683***	–0.0327	0.0103	–0.0160
Soil quality	–0.0320**	–0.0119	0.0240*	0.0240***	–0.0097	0.0357	–0.0234	–0.0153
Elevation	0.0209	–0.0106	–0.0160	–0.0047	–0.0561**	0.0595**	–0.0799***	–0.0095
Rainfall	–0.0149	–0.0285*	0.0256**	0.0248***	0.0228	–0.0132	0.0332	0.0016
Population density	0.0193	0.0321*	–0.0380***	–0.0225**	0.0056	–0.0517**	0.0467*	0.0343**
Distance to markets	0.0074	–0.0320*	0.0007	0.0268**	0.0491**	–0.0115	0.0299	0.0418**
Cooperatives	–0.0116	0.0256	–0.0074	0.0403***	–0.0227	–0.0100	–0.0117	0.0212
NGO credit	0.0109	0.0212	–0.0057	–0.0170	0.0218	0.0370	–0.0253	0.0059
Bureau of Agriculture	0.0009	–0.0141	0.0165*	0.0037	–0.0110	0.0131	–0.0499***	–0.0051
Adjusted R^2	–0.0042	0.0981	0.1340	0.3418	0.1385	0.0511	0.1127	0.0422

Note: Bureau of Agriculture factor has a strong component related to livestock promotion.

Dependent variable is proportion of farm households having specific livestock units.

***, **, *** mean coefficient is statistically significant at 10 percent, 5 percent, and 1 percent level, respectively.**

Table 4.8 Land use technologies

Technology	Mean	S.D.
Proportion of farmers using:		
Fertilizers	0.672	0.278
Pesticides	0.137	0.236
Herbicides	0.030	0.103
Improved seed	0.290	0.247
Livestock vaccine	0.728	0.276
Purchased feed	0.400	0.300
Proportion of farmers who:		
Burned to clear land	0.630	0.406
Fallowed fields for more than a year	0.185	0.299
Used improved fallow	0.015	0.082
Rotated crops	0.864	0.248
Used intercropping	0.499	0.394
Contour plowed	0.957	0.126
Mulched	0.006	0.051
Manured	0.623	0.280
Composted	0.208	0.251
Plowed in crop residues	0.072	0.206
Used green manure	0.002	0.014
Proportion of farmers making investments (since 1991) in:		
Stone terraces	0.515	0.305
Soil bunds	0.226	0.304
Check dams and gully stabilizers	0.408	0.298
Drainage ditches	0.148	0.297
Irrigation wells	0.009	0.053
Irrigation canals	0.241	0.314
Grass strips	0.013	0.066
Tree planting	0.575	0.364
Live fences	0.412	0.324
Private nurseries	0.001	0.010

manure, mulching, and plowing under crop residues are only rarely applied. Chemical fertilizers, livestock vaccines, and contour plowing are applied by more than two-thirds of the households. On the opposite end, herbicides, improved fallow, mulch, green manure, irrigation wells, grass strips, and private nurseries are used by fewer than 5 percent of the households.

We can identify some of the structural variables that influence the choice of land use practices and technologies (see Table 4.9). Fertilizers tend to be used on lower-quality soils in settings with higher population density and with good market access. Under these conditions, intensification of land use is mainly a demand-driven option. Pesticide use is similarly related to higher population density, which requires more intensive pest and disease control. Improved seeds are mainly used in areas with less-degraded soils. Vaccinations are mainly applied in high-potential agricultural areas. Improved feeding practices (i.e., more balanced feed menus based on crop residue grazing, cut and carry grass harvesting, and feed purchase) are found in low-rainfall areas with little institutional presence.

We notice that fallow is practiced on less-degraded soils in areas with low population density. Less population pressure allows fallowing as a practice for controlling degradation. Manure and composting are mostly applied in low-rainfall areas. The latter practice is most often found in areas with relatively good soils, and where NGOs and irrigation institutions are present.

Investments in soil and water conservation structures show some interesting results. Stone terracing is constructed where severe soil degradation is present. Live fences are found where soils are degraded but soil quality is inherently good and higher population densities permit labor-intensive investments. Other investments such as soil bunds, drainage ditches, and tree planting are also found in less-degraded areas. Cooperatives seem to enhance terracing but are less effective in tree planting. Availability of NGO credit is particularly linked to soil bunds and drainage ditches.

Credit Use

The most important sources of credit in the region are friends or relatives and NGOs, followed by the state BoA. Professional moneylenders and traders play an important role in some communities. Most credit provision is not very closely related to agro-ecological conditions (Table 4.10). Only the NGO REST focuses its activities mainly in highly populated areas with low rainfall and high soil degradation. Money lenders are the most important source of credit in villages where cooperatives and irrigation organizations are active. Formal credit provision is generally concentrated in areas with less degraded or good soils, where prospects for semi-commercial production prevail.

Welfare Implications

In Table 4.11 we present some development indicators extracted from the survey. These provide insight into the investments made for housing and schooling. Most houses have a dirt floor, but major differences appear with respect to the roof. Metal roofs are found in higher-rainfall areas with better market access and presence of cooperatives. The high rainfall makes an investment in metal roofs more important, and returns from trade and loans from local institutions allow farmers to make these investments. Literacy rates are higher in areas with less rainfall and higher population density. The presence of irrigation institutions and livestock promotion programs of the BoA is positively correlated with education efforts.

Table 4.9 Relationship between technology choice and development domain dimensions

Dimension	Fertilizers	Pesticides	Improved seed	Vaccinations	Improved feeding practices	Soil bunds
Constant	0.6636***	0.1455***	0.2904***	0.7229***	0.4184***	0.2249***
Soil degradation	–0.0179	–0.0440	–0.0728***	–0.0805***	0.0409	–0.0772**
Soil quality	–0.0795***	0.0024	0.0381	0.0630**	–0.0590*	0.1058***
Elevation	0.0004	–0.0234	–0.0071	0.0100	0.0122	–0.0501
Rainfall	0.0230	–0.0142	–0.0437*	–0.0257	–0.1025***	–0.0493
Population density	0.1076***	0.0767***	0.0254	0.0032	0.0438	0.0128
Distance to markets	–0.0625*	0.0044	–0.0185	–0.0029	0.0009	–0.0172
Cooperatives	0.0209	0.0438	0.0329	0.0499	–0.0944***	0.0109
NGO credit	0.0192	–0.0287	0.0264	–0.0005	–0.1004***	0.0651*
Irrigation institutions	0.0222	0.0183	0.0234			0.0304
Bureau of Agriculture				0.0240	–0.0010	
Adjusted R^2	0.1588	0.0670	0.0661	0.0698	0.1515	0.1586

Note: Dependent variable is proportion of farm households using a specific technology.

***, **, *** mean coefficient is statistically significant at 10 percent, 5 percent, and 1 percent level, respectively.**

Synthesis

The three core dimensions of the village development domains in Tigray have important implications for rural development options. Biophysical aspects, especially rainfall and temperature—and to a minor extent soil fertility—determine the

Table 4.10 Relationship between credit use and development domain dimensions, by credit source

Factor	NGO REST	Women's Bureau of Agriculture	Society of Tigray	Money lenders	Traders	Family and friends
Constant	0.4618***	0.2264***	0.0008	0.0470***	0.0010	0.5981***
Soil degradation	–0.0661**	–0.0025	–0.0003	0.0032	–0.0016*	–0.0989**
Soil quality	–0.0287	–0.0093	0.0032***	–0.0109	–0.0002	–0.0474
Elevation	0.0183	–0.0277	–0.0018	–0.0052	–0.0007	–0.0264
Rainfall	–0.0741**	–0.0437	0.0023**	–0.0085	–0.0008	–0.0661
Population density	0.0994***	0.0261	0.0015	–0.0031	–0.0005	–0.0394
Distance to markets	0.0375	–0.0582	–0.0013	0.0138	0.0005	–0.0775
Cooperatives	–0.0248	–0.0973***	–0.0012	0.0161	0.0066***	–0.0486
NGO credit	0.0504	0.0129	0.0011	–0.0565***	0.0000	–0.0863*
Irrigation institutions	0.0716**	0.0653*	0.0010	0.0215**	0.0036***	–0.1503***
Bureau of Agriculture	–0.0024	0.1733***	0.0005	0.0234***	0.0029***	0.0275
Adjusted R^2	0.1502	0.3229	0.0967	0.3414	0.4355	0.1301

Note: Dependent variable is proportion of farm households using specific credit sources.

***, **, *** mean coefficient is statistically significant at 10 percent, 5 percent, and 1 percent level, respectively.**

Gully stabilization	Drainage ditches	Fallow	Manure application	Compost application	Irrigation canals	Stone terraces	Tree planting
0.3973***	0.1389***	0.1780***	0.6282***	0.2555***	0.5058***	0.5973***	0.1958***
0.0427	–0.0672**	–0.0643*	–0.0071	–0.0327	0.1025***	–0.0671*	0.0054
0.1342***	0.0679**	–0.0003	–0.0433	0.0312	–0.0257	–0.0068	0.0447*
0.0626**	0.0196	0.0035	–0.0379	0.0074	–0.0041	0.0501	–0.0015
0.1093***	0.0719**	–0.0458	–0.0662**	0.0726**	0.0188	–0.0930**	–0.0628***
–0.0424	–0.0470	–0.0990***	–0.0368	0.0014	0.0141	0.0580	0.0366
0.0063	–0.0296	0.0305	0.0216	0.0601	0.0515	–0.0202	–0.0291
–0.0312	–0.0328	–0.0007	0.0155	0.0052	0.0820**	–0.1235***	0.0021
–0.0171	0.0963***	0.0499	0.0268	0.0474	0.0223	–0.0054	0.0699**
–0.0262	0.0632***	–0.0280	0.0165	–0.1036***	0.0352	0.0862**	0.0427*
			0.0227				
0.3535	0.1825	0.0392	0.0634	0.0758	0.1232	0.1067	0.1725

scope for crop choice and livestock production. Population density influences the degree of input intensification of cropping systems, whereas livestock intensification takes place in areas with lower population density. Formal credit is mainly concentrated in high-potential areas, but NGOs target credit to resource-poor regions and households. Market access and institutional organization appear as key

Table 4.11 Relationship between human development indicators and development domain dimensions

	Houses with metal roofs	Adult literacy	School-age children attending school
Constant	0.0916***	0.5304***	0.6573***
Soil degradation	0.0096	–0.0150	–0.0254
Soil quality	–0.0039	–0.0076	0.0283
Elevation	–0.0243	–0.0332	–0.0012
Rainfall	0.0457**	–0.0427**	–0.0473**
Population density	0.0562***	0.0506**	0.0750***
Distance to markets	–0.0604***	–0.0025	–0.0296
Cooperatives	0.0429*	0.0114	0.0387
NGO credit	–0.0193	0.0151	0.0244
Irrigation institutions	–0.0102	0.0169	0.0621***
Bureau of Agriculture	0.0205	0.0726***	0.0301*
Adjusted R^2	0.1308	0.1445	0.1698

Note: Dependent variable is proportion of farm households meeting the human development indicator criterion.
***, **, *** mean coefficient is statistically significant at 10 percent, 5 percent, and 1 percent level, respectively.**

incentives for cropping systems intensification and for enhancing investments in soil and water conservation activities. In a similar vein, investments in housing are made under more favorable agro-ecological, market, and institutional conditions, whereas investments in schooling are an attractive device for enhancing engagement in nonfarm employment in low-potential areas with high population density.

Discussion and Conclusions

We developed in this chapter a quantitative methodology for identifying relevant dimensions for village development domains that determine the scope for specific land use and production systems. This analysis can be useful both for extension and policy purposes; results can be used as a first step for the definition of recommendation domains for technical assistance services and for the identification of effective incentive regimes that permit farm household resource intensification. In addition, the methodology gives insight into the different local development pathways and the critical factors that influence farmers' livelihood strategies.

With the data derived from community surveys, it proved to be possible to extract the relevant dimensions of local development domains. We distinguished among agro-ecological potential, population density, and market access. The agro-ecological potential is by far the most complicated dimension because it includes multiple aspects: rainfall, soil quality, soil degradation, and elevation. Rainfall and soil quality determine the cropping potential, and altitude (as a proxy for temperature) needs to be taken into account because it determines the feasible options for crop diversification within the agricultural system. The distance to market outlets is relevant to determine whether these activities can be made economically attractive.

The relative independence of the critical dimensions of the development domains has been evaluated using regression methods. The correlations among these development domain dimensions are very low: the correlation is less than 1 percent between the level of degradation and rainfall and between population density and soil quality, and less than 4 percent between market access and altitude. The R^2 for most regressions is so low that we can safely ignore these interdependencies in our further analysis.

Understanding current production systems in terms of cropping patterns, livestock activities, and technology choice in relation to development domain dimensions gives a good indication of how development has occurred in the past. Although the past is not the only determinant of future pathways, and dynamic factors are not captured explicitly, it constitutes a relevant frame of reference. The systematic quantification of development domains and the predominant livelihood strategies therein provide a benchmark against which development strategies can be evaluated.

The occurrence of predominant cropping systems mainly depends on the variables pertaining to rainfall and altitude (temperature). These variables determine the suitability of a certain agro-ecological zone for certain land use systems. Soil quality and degradation only play a secondary role. In some cases crop choice depends on factors such as population density and market access. Maize production is found in more densely populated areas where otherwise sorghum would prevail. Better market access in the low-altitude areas seems to favor millet production. Market access is very important in the adoption of cash crops.

The development of livestock production depends on different factors. Rainfall and availability of pastures and feed are required for the maintenance of oxen. Ox ownership is fairly widespread in Tigray to guarantee timely land preparation. However, the number of oxen per household varies considerably. More oxen per household are found in settings where soils are of better quality and population densities are lower, permitting the availability of sufficient pasture and feed of good quality. Ox ownership tends to be greater in more remote areas. Under conditions of poor soil quality, dairy production and beekeeping arise as alternative strategies for farmers who possess stable market outlets. When markets are more remote, small stock production for local use appears as a useful alternative.

The selection of suitable and appropriate land use technology depends strongly on soil quality and the level of land degradation. The use of improved seeds depends on market access, whereas the use of external inputs is related to higher population density. In a similar vein, gully stabilization mainly occurs in erosion-prone areas located at higher elevations receiving higher rainfall on terrains with relatively good soil, whereas compost application is mostly done in low-rainfall settings to maintain soil fertility and improve moisture retention. This implies that farmers seem to be more inclined toward intensification of their land use systems in villages with high population pressure, especially when soil degradation is not yet a large problem. In general, adoption of improved land use technologies is positively correlated with better soils or less-degraded soils.

Geographic targeting of interventions requires the identification of appropriate technologies, followed by the application of suitable incentives. This means that technology packages should be oriented toward the specific development domains, taking into account the institutional and market conditions that prevail in each village. Institutional factors appear to play a major role in defining the incentive framework. However, institutional support by the state or NGO agencies is not fully independent of the other development dimensions. The presence of marketing institutions is relevant for the selection of commercially oriented cropping activities, and credit proved to be important for the expansion of oxen traction. For the adoption of improved land use practices, the availability of credit plays an overriding role.

Access to markets tends to be less important than institutional support. There are indications that farmers are able and willing to make the necessary investments for improving production and yields under conditions of increasing population pressure because some investment indicators are positively correlated with population density. Financial services also play an important role in controlling land degradation. Formal credit from state development agencies tends to be concentrated in less degraded areas because demand for credit is higher in better-endowed areas. By contrast, NGO credit provisions focus on less-favored areas.

The results in this chapter indicate some promising perspectives for further research. Making use of community-level surveys for collecting information on resource endowments, predominant land use patterns, and production systems enables the identification of some common dimensions of different development domains. Although this does not directly provide an indication of appropriate development pathways per se, the results from this analysis are useful for identifying feasible options when combined with location-specific information. Although the methodology in itself is sufficiently robust, further research at the farm household level is required to identify the farm household's responsiveness to specific policy incentives. The results of the stratification can also be used for developing bioeconomic household and village models that reveal the welfare and sustainability implications of different incentive regimes (see Kruseman 2000; Ruben, Kruseman, and Kuyvenhoven 2006).

The methodology developed in this chapter generates structural information that needs to be complemented by local case studies that could reveal other more behavioral motives for farming systems choice and livelihood strategies. This approach can be considered as a step toward differentiating predominant development patterns from idiosyncratic situations. Moreover, the approach offers a more generalized analysis compared to location-specific farming systems research, which provides a useful benchmark for comparing alternative development interventions. It is not meant to offer exact policy recommendations, however, but rather provides guidance to the directions in which these policy recommendations might be found.

Notes

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1. Diversity between household configurations in terms of differences in life cycle and intra-household relations can, of course, be registered, as indicated by Bauer (1977) and Abate (1995).

2. The lowest administrative level in Ethiopia is the *tabia.* In Tigray a number of *kushets* (hamlets) can be distinguished within the *tabia.* In this chapter we refer to *kushets* as villages, although some of the data we use are at the *tabia* level.

3. The notion of recommendation domains with fine-tuned development interventions was suggested as a general methodological framework in Farming Systems Research (FSR) in the 1980s. These approaches tended to be less formalized with a much broader set of criteria defining the domains than we use in our analysis. By narrowing down the criteria to three broad dimensions, we make the approach much more comparable across geographic locations, thus addressing one of the major criticisms against FSR as being too site-specific.

4. For details on the village survey, see Pender et al. (2001a).

5. Farmers' perceptions of soil properties are based on farmer perceptions of soil quality and are therefore a good measure of perceived short- and medium-term land use potential.

6. The use of SUR with identical X matrices takes into account that the analysis considers the activities as being done not in isolation but as parts of broader livelihood strategies. We report on this elsewhere in more detail (Kruseman, Ruben, and Tesfay 2006).

7. We choose to include population density in the factor analysis in order to get a normalized value for this variable.

8. In order to maintain meaningful variables, we combined some of the variables through a number of data reduction steps.

9. Only total rainfall is used as a determinant of development domain dimension because data on interannual and intraseasonal variation is either missing or incomplete.

10. Tigray is a mountainous area, and indicators for altitude depend on the criteria used for defining what is relevant. By using two data sources we attempt to reduce biases. One source is the village-level survey, and the other is based on general geographic information.

11. We have chosen not to use all the variables related to distance available in the community survey. A number of variables related to walking time and distance to local (grain mills) and social infrastructure (schools and medical services) are excluded from the analysis. They load on a separate factor that is not expected to have an important influence on development domains.

12. Soil quality (SQ) is considered as inherent soil quality based on prevalent soil types, not the result of cultivation practices. Testing for endogeneity does not indicate otherwise.

13. We relied on three-stage least-squares to determine the interdependence of the development domain dimensions using the truly exogenous factors (inherent soil quality, rainfall, and elevation) as instruments. Although some coefficients are significantly different from zero, all adjusted R^2 values are well below zero, indicating that the system of equations cannot adequately explain any variation. It can thus be concluded that there is no correlation among the error terms.

14. The weights used range between 1 and –1 to indicate how the factor scored on agricultural potential.

15. Superimposing the results of this analysis with recently defined agro-ecological zones of the country might be helpful in guiding research priorities and development needs.

16. We focus on actual use of credit, given the supply by local institutions, because credit use is an endogenous decision of farm households.

17. Three-stage least-squares is the seemingly unrelated regression method with correction for endogeneity. The seemingly unrelated regression method (SUR) applies to a system in which each

equation has an endogenous variable on the left side and only exogenous variables on the right side. As in the standard regression case, the disturbances are assumed to be uncorrelated with the exogenous variables. Each equation of this kind of system could be estimated by regression, equation by equation. However, if the disturbances of the equations are correlated, the SUR estimator is more efficient because it takes into account the entire matrix of correlations of all the equations. The SUR estimator minimizes the determinant of the covariance matrix of the disturbances.

18. The excluded endogenous variables all represent minor activities with only few observations.

19. The existence of some rotations appears when factor analysis is done on cropping patterns (not reported here).

20. This is an interesting finding because sorghum is usually not considered as a high-rainfall-demanding crop. However, rainfall is limited in the highlands of Tigray, even in relatively "higher rainfall" parts of this region.

21. This does not exclude the fact that maize is also grown in areas with little NGO presence.

22. The statistical relationships found in the data do not exclude the occurrence of other situations, such as beekeeping in low-population-density areas, but rather, they indicate predominant patterns.