Diversity and Development Domains in the Ethiopian Highlands

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Policies for Sustainable Land Management in the Ethiopian Highlands

IFPRI-WUR project *Policies for Sustainable Land management in the Ethiopian Highlands*

Land degradation problems--including soil nutrient depletion, soil erosion, deforestation and other concerns--are severe in the Ethiopian highlands. These problems are contributing to low and declining agricultural productivity, poverty and food insecurity. The proximate causes of these problems are relatively well known. Underlying these proximate causes are many more fundamental causes. These more fundamental causes are affected by many aspects of government policy. Assessing the impact of different causal factors and identifying effective policy strategies to improve land management is a critical research challenge that has not yet been solved. In part, this is due to the complexity of factors influencing the problem. "One-size-fits-all" policy or program approaches are unlikely to be broadly successful. There is thus a general need and desire for more effective targeting of policy strategies towards specific regions and groups, although this depends on improved information about the potential impacts of alternative strategies.

The long-term goal, immediate purpose and specific objectives of the project are as follows:

Long-Term Goal:
To contribute to improved land management in the Ethiopian highlands, in order to increase agricultural productivity, reduce poverty and ensure sustainable use of natural resources.

Immediate Purpose:
To help policy makers in Ethiopia identify and assess strategies, including technology development policies, to achieve that goal.

Specific Objectives:

- To identify the key factors influencing land management in the Ethiopian highlands and their implications for agricultural productivity, sustainability and poverty;
- To identify and assess policy, institutional and technological strategies to promote more productive, sustainable, and poverty reducing land management;
- To strengthen the capacity of collaborators in the Ethiopian highlands to develop and implement such strategies, based upon policy research; and
- To increase awareness of the underlying causes of land degradation problems in the Ethiopian highlands and promising strategies for solving the problems.

The research takes place in Tigray, Northern Ethiopia. The project started in January 2001 and will continue until December 2003.

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More information can be found at the project web site:
www.sls.wau.nl/oe/pimea

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List of *Policies for Sustainable Land Management in the Ethiopian Highlands* working papers:

2002-01	Kruseman, G., J.Pender, G.Tesfay and B.Gebremedhin *Village stratification for policy analysis: multiple development domains in the Ethiopian Highlands.*
2002-02	Kinfe Abraha Weldemichael *Public and private labour investments and institutions for soil and water conservation in Tigray, Northern Ethiopia.*
2002-03	Boetkees, S. *Rural credit and soil and water conservation: a case study in tigray, Northern Ethiopia.*
2002-04	Kruseman, G., R.Ruben, G. Tesfay *Diversity and Development Domains in the Ethiopian Highlands*

PIMEA WORKING PAPER 04

Diversity and Development Domains in the Ethiopian Highlands

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Wageningen, December 2002

Abstract

In the discussion on targeting of development interventions there is an ongoing debate on the usefulness of geographic targeting versus targeting of specific household types. In this paper we examine the degree to which there is heterogeneity in the diversity of livelihood strategies in comparable geographic areas. We use the concept of development domains to quantify differences between specific geographic areas (communities).

***Keywords**:* *Development pathways; livelihood strategies; village stratification; agricultural intensification; Northern Ethiopia.*

1 Introduction

Development, diversity, agricultural intensification, soil degradation,

The concept of development domains can be used to facilitate the targeting of development interventions. Major dimensions of development domains usually include agricultural potential, market access and population density. These aspects adequately distinguish between situations where Malthusian or Boserupian development in likely to take place. 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 occurs 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 *et al.,* 1994). In these setting, 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 already reached at rather low population densities (Kruseman, 2000).

The identification of development potentials can be addressed in a quantitative fashion, identifying the possibilities for targeting of interventions (Kruseman *et al,* forthcoming). This implies the use of precise definitions of the critical dimensions that determine different strategic development options. The dimensions commonly used for distinguishing between development domains are; (i) agricultural potential (biophysical environment), (ii) population density and (iii) market access (socio-economic environment). These dimensions are exogenous to the households that try to cope with their biophysical and socio-economic environment. Household decisions regarding land use practices and production technologies result in particular livelihood strategies.

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 between villages is more important compared to heterogeneity amongst households, targeting can be safely done at community level (Bigman and Fofack, 2000). Geographical targeting can then be considered as an effective strategy for selectively enhancing a process of agricultural intensification.

In this paper we analyse to what degree the heterogeneity in major indicators for agricultural production depend on development domain dimensions. For each indicator separately we look at the explanatory power of the development domain dimensions. Then finally we look at the degree to which the heterogeneity itself in otherwise similar settings can be explained by the development domain dimensions. The remainder of the paper is structured as follows. In the next section the concept of development domains is discussed within the context of the Ethiopian highlands. Next we briefly discuss the methodology used in the analysis. Then we present the results and finally derive some conclusions with respect to the importance of heterogeneity amongst similar environments.

2 Development domains in the Ethiopian highlands

The northern Ethiopian highlands face serious problems related to the high population density and the limited agro-ecological potential. Regional programs for soil and water conservation have been launched that intend to increase land and labour productivity. However, given the modest public resources that are available, some choices have to be made where to target specific activities. Not all activities are suitable for each community and different communities are likely to benefit most from different 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 between communities and to select the most appropriate development strategies.

The concept of development domains can be used to identify the critical dimensions that influence the adoption of certain resource management practices (Pender *et al.,* 1998; Fitsum Hagos *et al.,* 1999). This approach is based on the notion that it is possible to disentangle the core elements of successful local development strategies that can be subsequently addressed through a selective offer of technologies or services.

One of the main hypotheses of 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 absolute comparative advantage of producing different kinds 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 multi-dimensional 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.

Market access is equally important for determining the comparative advantage of a specific locality for producing certain tradeable commodities. Market access also involves various dimensions and encompasses o.a. distance to roads, quality of roads, travel time, distance to markets and urban centers, degree of competition, information costs, 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 before-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 (Goetz, 1992; Omamo, 1998)

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; Biswanger and McIntire, 1987). It is related 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 infrastructural 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 of Machakos, Tiffen *et al.* (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 the population pressure. The absence of such market outlets in other parts of East Africa has led to accelerated degradation. In areas with low population density and a limited agricultural potential zone where market access is constrained, small changes in population dynamics can set off 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, 1991).

In summary, the variables of market access and population pressure are very often correlated at local level. Increasing population pressure may lead to better market access, while 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, we can identify settings with high and low population density both in remote and accessible regions. In addition, there is no clear correspondence between population density and the available agroecological potential. We can therefore differentiate with the three criteria a total number of eight different categories of situations. In the following we will discuss these settings and identify their importance for the selection of typical land use practices.

3 Methodology

To get a handle on the classification of situations in the highlands of Ethiopia a more statistically robust methodology is welcomed. Development domain dimensions are quantified using multivariate analysis on community level data sets (Kruseman, *et al.*, forthcoming). In this procedure a small set of independent factors is derived from a large number of indicator variables that describes the development domain dimensions in terms of agricultural potential, market access and population density.

The methodology makes use of the availability of a village level survey of 100 households in the case study area. The goal of the exercise is to classify each village (kushet) into a three dimensional matrix of factors influencing development potential. At the same time an analysis of livelihood strategies derived from the same survey will give an indication of the development opportunities in each category.

For each dimension there are usually a number of different variables available that are related to it. To choose a useful proxy variable is not always easy. By using factor analysis (using principal component analysis) to reduce the data, single quantitative measures are derived for each main factor. This has the advantage of being to use all the variables in the data set that are relevant while preventing to a large extent the occurrence of dependency amongst the development domain dimensions.

Because we are not able to *a priori* determine if the development domain dimensions are completely independent, we test for this independence using three-stage least squares and seemingly unrelated regression. Once we have quantified the development dimensions we can do a rough analysis on the variables related to livelihood strategies and development opportunities within the community survey. This analysis consists of regressing the development domain dimensions on those variables.

We use a third order polynomial functional form to regress the development domain dimensions on sets of indicator variables observed in the survey data.

$$Y_{ij} = \sum_k \beta^1_{jk} X_{ik} + \sum_{k,l} \beta^2_{jkl} X_{ik} X_{il} + \sum_k \beta^3_{jk} X_{ik} X_{ik} X_{ik} + \mu_{ij} \qquad (1)$$

Since it is plausible that the error terms of the equations are correlated we use seemingly unrelated regression (SUR) to get unbiased estimates. The main advantage of SUR is that the probability of rejecting the significance of coefficients diminishes. We use this analysis to determine to what extent indicator variables depend on these development domain dimensions. We then quantify the observed heterogeneity in indicator variables by:

$$\sum_j |\mu_{ij}| = \sum_k \beta^1_k X_{ik} + \sum_{k,l} \beta^2_{kl} X_{ik} X_{il} + \sum_k \beta^3_k X_{ik} X_{ik} X_{ik} + e_i \qquad (2)$$

The indicator variables we consider are cropping patterns, livestock use, technology choice and investment in soil water conservation (SWC) structures.

For livestock use and investment is SWC structures this striaght forward approach can be used, for cropping patterns and technology choice we use a slightly different approach. We do this because it is plausible to assume that cropping patens are partly dependent on past investments and that technology choice is correlated with cropping patterns, livestock use and investment. These variables themselves are determined by the development domain dimensions and hence we have endogeneity.
To solve this issue we must derive a systems of equations. We write the model in matrix notation as:

$$\mathbf{AY} = \mathbf{BX} + \mathbf{U} \qquad (3)$$

with **Y** is an (n x g) matrix of endogenous variables, **X** is an (n x k) matrix of exogenous variables (development domain dimensions), **A** denotes a (g x g) matrix of coefficients, **B** denotes (k x g) matrix of coefficients and **U** denotes an (n x g) matrix of error terms. This model contains too many coefficients to estimate directly.
In our case we assume that we are only dealing with endogeneity and not with simultaneity, hence matrix **A** has specific structure. Imposing A_{ii} = 1 as normalization

on the equations the relationship for the other coefficients takes on the form of a nested structure:

$$\begin{bmatrix} \mathbf{I} & 0 & 0 & 0 \\ -\mathbf{A}_{21} & \mathbf{I} & 0 & 0 \\ 0 & 0 & \mathbf{I} & 0 \\ -\mathbf{A}_{41} & -\mathbf{A}_{42} & -\mathbf{A}_{43} & \mathbf{I} \end{bmatrix}$$

with $\mathbf{A}_{ij}$ being (g_j x g_i) blocks of multivariate linkage coefficients.
Solving the model with three stage least squares is not a feasible option because there is a lack of degrees of freedom, since n=82 (observations), k=38 (constant, development domain dimensions), g1=9 (investment) , g2=15 (crops), g3=9 (livestock), g4=17 (technology), such that df=-6.
The nested structure of the model allows us to pursue a different route. For investment and livestock there are no endogenous variables hence straightforward seemingly unrelated regression.

$$\mathbf{IY}_i = \mathbf{B}_i\mathbf{X} + \mathbf{U}_i \qquad (4)$$

for i = 1,3. For crops the model becomes:

$$\mathbf{IY}_2 = \mathbf{B}_2\mathbf{X} + \mathbf{A}_{21}\mathbf{Y}_1 + \mathbf{U}_2 \qquad (5)$$

First we estimate:

$$\mathbf{IY}_i = \mathbf{B}_{ia}\mathbf{X} + \mathbf{U}_{ia} \qquad (6)$$

for i = 2, where $\mathbf{B}_{2a}$ are the direct and indirect effects of $\mathbf{X}$ on $\mathbf{Y}_2$.

$$\mathbf{B}_{2a} = \mathbf{B}_2 + \mathbf{A}_{21}\mathbf{B}_1$$

and $\mathbf{U}_{2a}$ is the combined effect of error terms

$$\mathbf{U}_{2a} = \mathbf{U}_2 + \mathbf{A}_{21}\mathbf{U}_1 \qquad (7)$$

which can be estimated using OLS.
In the final step in the procedure is to redo the regression using the results from equation (7). Inserting the estimated value of the residuals ($\hat{\mathbf{U}}_{ia} = \mathbf{A}_{ij}\mathbf{U}_j$) in equation (8) implies that ideally $\mathbf{C}_i = \mathbf{I}$. Again we use SUR to account for correlated residuals.

$$\mathbf{IY}_i = \mathbf{B}_{ia}\mathbf{X} + \mathbf{C}_i\hat{\mathbf{U}}_{ia} + \mathbf{U}_i \qquad (8)$$

For technology choice we have a double nested model which can be estimated in a similar way using equation (6) so that $\mathbf{B}_{4a}$ are the direct and indirect effects of $\mathbf{X}$ on $\mathbf{Y}_4$.

$$\mathbf{B}_{4a} = \mathbf{B}_4 + \mathbf{A}_{41}\mathbf{B}_1 + \mathbf{A}_{42}\left(\mathbf{B}_{2a} - \mathbf{A}_{21}\mathbf{B}_1\right) + \mathbf{A}_{43}\mathbf{B}_3$$

and $\mathbf{U}_{4a}$ is the combined effect of error terms

$$\mathbf{U}_{4a} = \mathbf{U}_4 + \mathbf{A}_{41}\mathbf{U}_1 + \mathbf{A}_{42}\left(\mathbf{U}_{2a} - \mathbf{A}_{21}\mathbf{U}_1\right) + \mathbf{A}_{43}\mathbf{U}_3 \qquad (9)$$

which can again be estimated using OLS.
In the final step the results from equation (9) are used to estimate equation (8).
The implication of this approach for the regression on heterogeneity is that the μ_{ij} in equation 2 corresponds to the elements of $\mathbf{U}_i$ and not $\mathbf{U}_{ia}$.

4 Results

The final results of the regression models presented above are summarized in Table 1. For the present analysis we are less interested in the nature of direct and indirect effects of development domain dimensions on the explanation of investment decisions, predominant cropping patterns, livestock use and technology choice. This is discussed elsewhere (Kruseman *et al.*, 2002; 2003) However, we are interested in the degree in which these indicators of production systems are explained by the development domain dimensions. We observe the degree to which the indicator variables are explained by development domain dimensions as a combined result of direct and indirect effects. For many of the indicators, using the flexible third order polynomial functional form, we are able to explain a large portion of the variation. There are exceptions however, especially in those cases where it concerns only small proportions of farm households engaging in a certain activity. With respect to investments this is the case for grass strips and irrigation wells. However private nurseries although only important for very few farmers can be explained by the development domain dimensions. With cropping patterns the low explanatory value of development domain dimensions is seen with sesame. With technology choice green manure application is explained to a large extent by a combination of past investments, cropping patterns and livestock use and to a lesser extent by development domain dimensions, while mulch is not explained by the variables in the model. Sometimes high occurrence of an indicator variable is also linked an even spread over the sample which leads to low explanatory power, as is the case with no oxen, and to a lesser extent tree planting, stone terraces, and donkey ownership. However not all variation is explained. Even though the heterogeneity present in these indicator variables, graphically presented in Figures 1 through 4, cannot be explained directly or indirectly by the development domain dimensions, the occurrence of deviations from the pattern might be. As one can observe in the graphical representations of the residuals (the unexplained parts of the indicator variables) there are quite a number of both positive and negative outliers. By summing the absolute values of the residuals of each of the regressions we get an indicator for the degree to which the indicators for agricultural production deviate from the expected pattern. What we would like to know is if this index is related to the development domain dimensions. Again we use a third order polynomial functional form. The results are summarized in Table 2.

The analysis of third order polynomial regression functions can be puzzling because of the combined effects. Table 2 indicates that with respect to past investments somewhat more heterogeneity is found at the extremes of elevation levels, but notably in the center with respect to rainfall and population density. The most important conclusion is that institutional presence leads to a more variety in investments not so much linkage between specific institutions and investments. In total 30% of the diversity can be explained in this way.

Table 1a Degree to which production system indicators are explained by direct and indirect effects of development domain dimensions and other (endogenous) production system indicators in their own right.

	Production system indicator characteristics (%)		Variance explained by the model (%)			
	Kushets with:	Farm households engaging in activity if present (on average)	Development domain dimensions	Investment decisions	Investment decisions, cropping pattern, livestock use	Total
Investment decisions						
Drainage ditches	30	49	42			42
Grass strips	6	21	0			0
Gully stabilisation	97	42	44			44
Irrigation canals	54	45	20			20
Irrigation wells	6	15	0			0
Private nurseries	2	6	71			71
Soil bunds	57	40	38			38
Stone terraces	94	55	18			18
Tree planting	78	74	14			14
Cropping pattern						
Barley	84	26	75	6		81
Teff	92	22	43	2		45
Maize	87	15	39	14		53
Wheat	64	17	57	2		59
Sorghum	51	18	56	13		69
Finger millet	64	12	29	12		41
Faba beans	63	7	42	12		54
Millet	49	6	23	7		30
Chick pea	66	4	56	14		70
Filed peas	48	5	27	5		32
Flax	71	3	8	39		47
Lentils	49	4	43	7		50
Haricot beans	14	6	53	4		57
Sesame	2	15	5	0		5
Niger seed	29	3	14	23		37
Livestock use						
No oxen	100	24	0			0
One ox	100	42	25			25
Two oxen	97	26	33			33
More than 2 oxen	66	14	34			34
Cows	97	39	28			28
Goats	86	33	39			39
Sheep	84	33	32			32
Donkeys	97	50	18			18
Beehives	85	20	25			25

Table 1b Degree to which production system indicators are explained by direct and indirect effects of development domain dimensions and other (endogenous) production system indicators in their own right.

	Production system indicator characteristics (%)		Variance explained by the model (%)			
	Kushets that apply:	Farm households engaging in activity if present (on average)	Development domain dimensions	Investment decisions	Investment decisions, cropping pattern, livestock use	Total
Technology choice						
Burn crop residues	82	77	43		22	65
Compost	60	35	60		26	86
Contour plowing	100	96	46		27	73
Crop residues incorporation	16	45	52		25	77
Crop rotation	96	90	67		24	91
Fallow	51	36	49		29	78
Feed	83	48	49		39	88
Fertiliser	99	68	62		23	85
Green manure	2	10	19		47	66
Herbicide	18	16	10		36	46
Improved fallow	5	30	11		36	47
Intercropping	77	65	51		31	82
Manure application	93	67	60		22	82
Mulch	2	30	23		0	23
Pestcide use	42	33	57		22	79
Improved seed	88	33	56		25	81
Vaccinations	94	77	59		28	87

With respect to crops more diversity is found in high elevation areas and areas closer to markets. High population density areas tend to be less heterogenous just as we find less diversity on poor and degraded soils. Finally diversity in cropping patterns is also linked to the presence of credit by REST. The presence of NGOs with their extension activities leads to crop diversification. However the type crop diversification is not the same in otherwise similar communities due to differences in emphases placed by the NGOs. More than 37% of the diversity can be explained this way.

Diversity in livestock systems is linked to soil quality but in a complex and not transparent way. More diversity in livestock systems is found at lower altitudes. Less diversity with lower rainfall. Only 18% of the heterogeneity is explained.

Diversity in technology choice is found in places with an average market access, with poorer soils in the higher elevation areas. Some 40% of diversity is explained this way. It should be noted that in the very remote areas and in areas with very high rainfall more diversity can be observed.

Table 2 Relationship between indicators for heterogeneity for investment, crops, livestock and technology and development domain dimensions.

	Investment	Crops	Livestock	Technology
Mean	0.9761	0.4668	0.7922	0.8852
Median	0.9389	0.4611	0.7995	0.8089
Maximum	2.3281	0.7809	1.4956	1.9776
Minimum	0.2309	0.1228	0.2452	0.1426
Std. Dev.	0.3799	0.1532	0.2954	0.3893
Skewness	0.8429	-0.1534	0.2480	0.3410
Kurtosis	4.0332	2.2856	2.2857	2.7145
Jarque-Bera	13.6839	2.1159	2.5835	1.8675
Probability	0.0011	0.3472	0.2748	0.3931
Observations	84	84	82	82
Constant	1.2053 ***	0.5076 ***	1.0330 ***	1.3436 ***
Degree of soil degradation (SD)	-0.0660	-0.0035	-0.1609 **	0.1166
Inherent good soils (GS)	0.0631	0.0368 *	0.0909 *	-0.0916
Elevation (EL)	-0.2170 **	-0.0262	-0.1950 **	-0.0560
Rainfall (RF)	-0.0518	-0.0090	-0.1093	-0.0951
Population density (PD)	-0.0329	-0.0084	0.0189	-0.0232
Distance to markets (DM)	0.0797	-0.0676 ***	0.0128	-0.1162 *
SD*SD	-0.0292	0.0181	-0.0328	-0.0422
GS*GS	-0.0102	-0.0254	-0.0597 *	-0.0730 *
EL*EL	-0.0584	-0.0935 ***	-0.0178	-0.1628 **
RF*RF	-0.1260 **	-0.0201	-0.1419 **	-0.0669
PD*PD	-0.1609 **	-0.0060	-0.0287	-0.1291
DM*DM	-0.0270	-0.0554 **	0.0095	-0.1870 ***
SD*GS	-0.0287	0.0282 **	-0.0067	0.0188
SD*EL	-0.0061	-0.0213	0.0595	-0.1406 ***
SD*RF	-0.0869 *	-0.0065	0.0299	-0.0170
SD*PD	-0.0593	0.0017	0.0036	-0.0147
SD*DM	0.0651	-0.0047	-0.0316	0.0005
GS*EL	-0.0188	-0.0011	0.0108	-0.0680
GS*RF	0.0357	0.0073	0.0367	-0.0632
GS*PD	0.0013	0.0152	0.0093	0.0599
GS*DM	0.0072	0.0172	-0.0121	0.0115
EL*RF	-0.1600 **	-0.0159	0.0055	-0.2521 ***
EL*PD	0.2218 *	0.1991 ***	0.0407	-0.0282
EL*DM	-0.0304	-0.0934 **	0.0491	-0.2539 **
RF*PD	-0.0117	0.0300	0.0713	-0.0197
RF*DM	0.0669	-0.0453	0.1385 *	-0.2548 ***
PD*DM	-0.0286	0.0580 *	0.0156	0.0848
SD*SD*SD	0.0274	-0.0092	0.0749 ***	-0.0712 **
GS*GS*GS	-0.0002	-0.0016	-0.0075	-0.0118
EL*EL*EL	0.0815 ***	0.0264 **	0.0333	0.0395
RF*RF*RF	0.0023	0.0105	0.0361	0.0586 *
PD*PD*PD	0.0109	-0.0141	-0.0002	0.0189
DM*DM*DM	-0.0055	0.0134	-0.0137	0.0457 *
Presence of cooperatives	0.0993 ***	-0.0045	-0.0057	-0.0925 **
Absence of irrigation institutions	-0.1902 ***	0.0032	-0.0223	-0.0227
Presence of livestock promotion	0.0935 ***	0.0067	0.0367	-0.0356
Presence of REST credit	0.1130 **	0.0377 **	0.0044	-0.0412
Adjusted R2	0.3058	0.3743	0.1889	0.4010
Observations	84	84	82	82

Note: *** 99% significance level, ** 95% significance level, 90% significance level

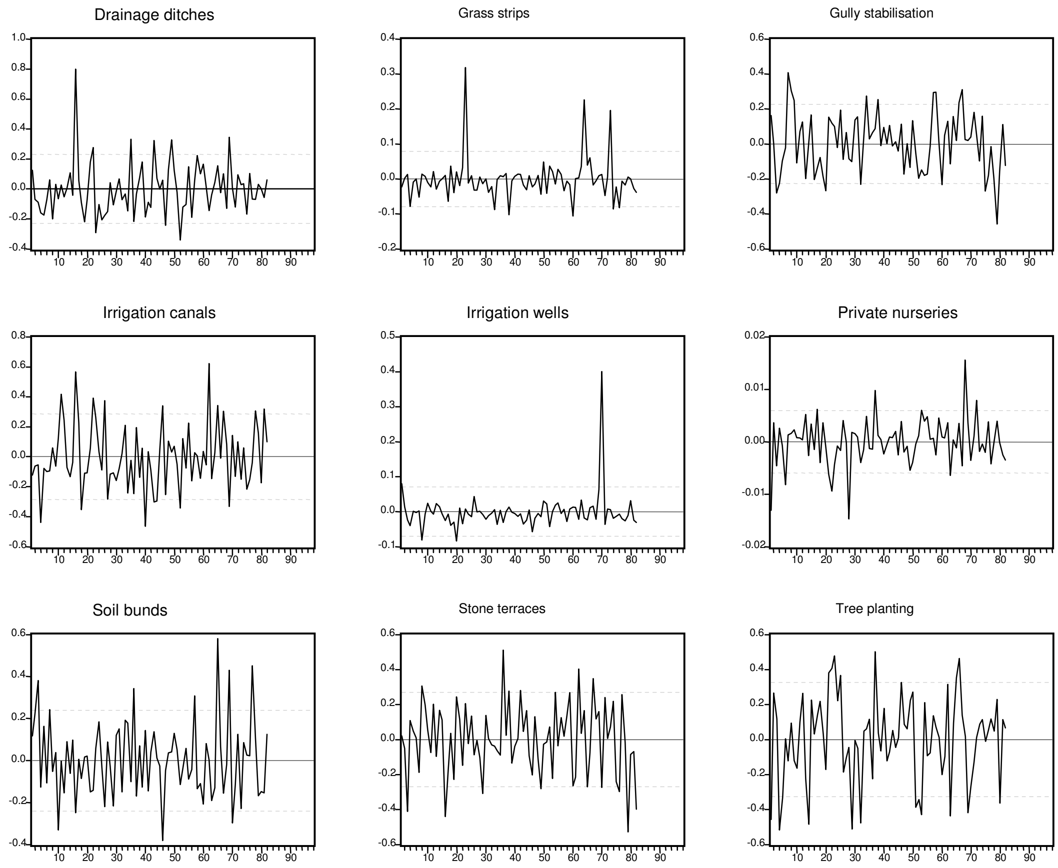

Figure 1 Residuals from third order polynomial estimation of proportion of farmers having invested in soil and water conservation measures explained by development domain dimensions

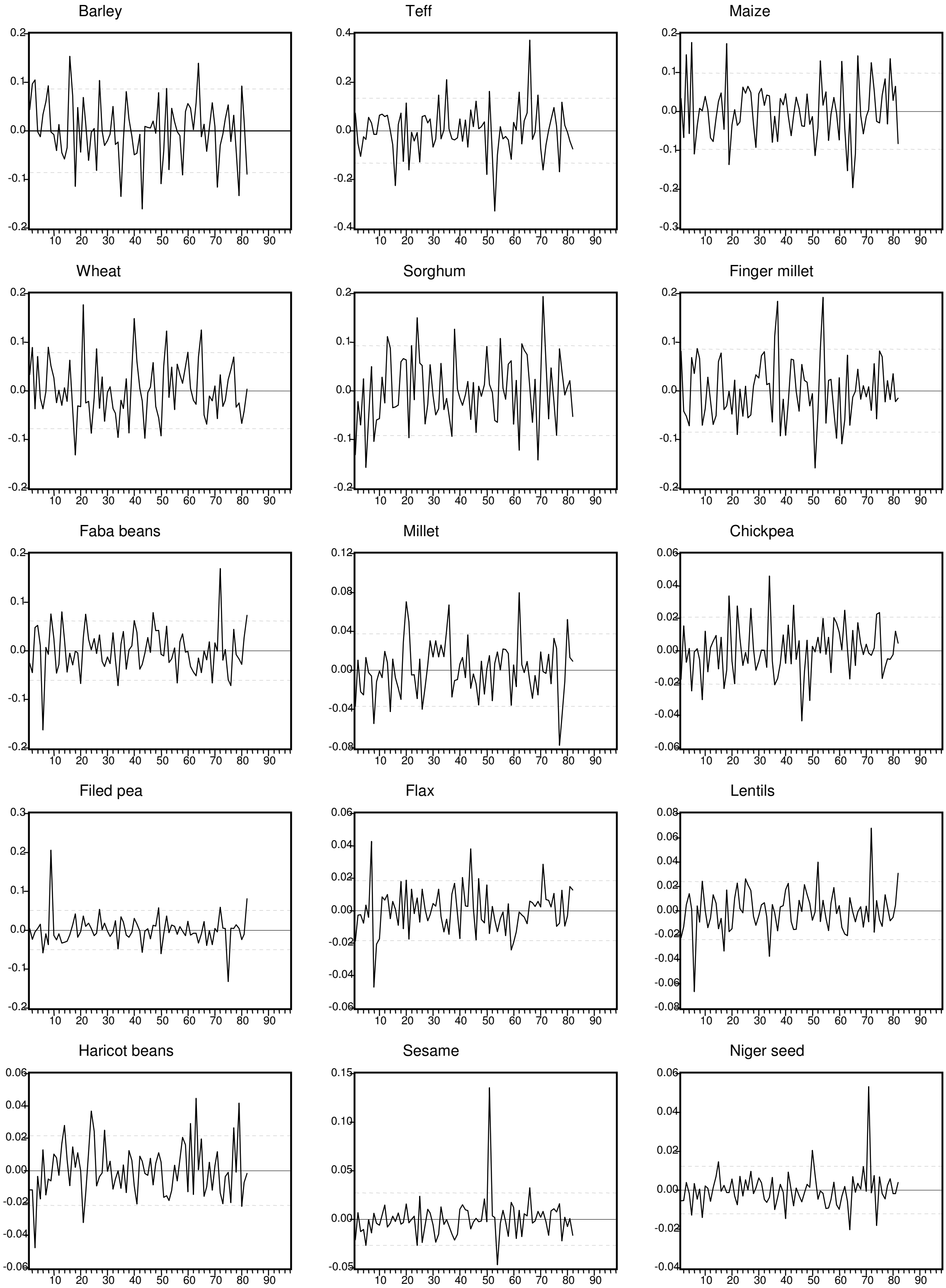

Figure 2 Residuals from third order polynomial estimation of proportion of farmers growing crops explained by development domain dimensions dimensions (direct and indirect effects).

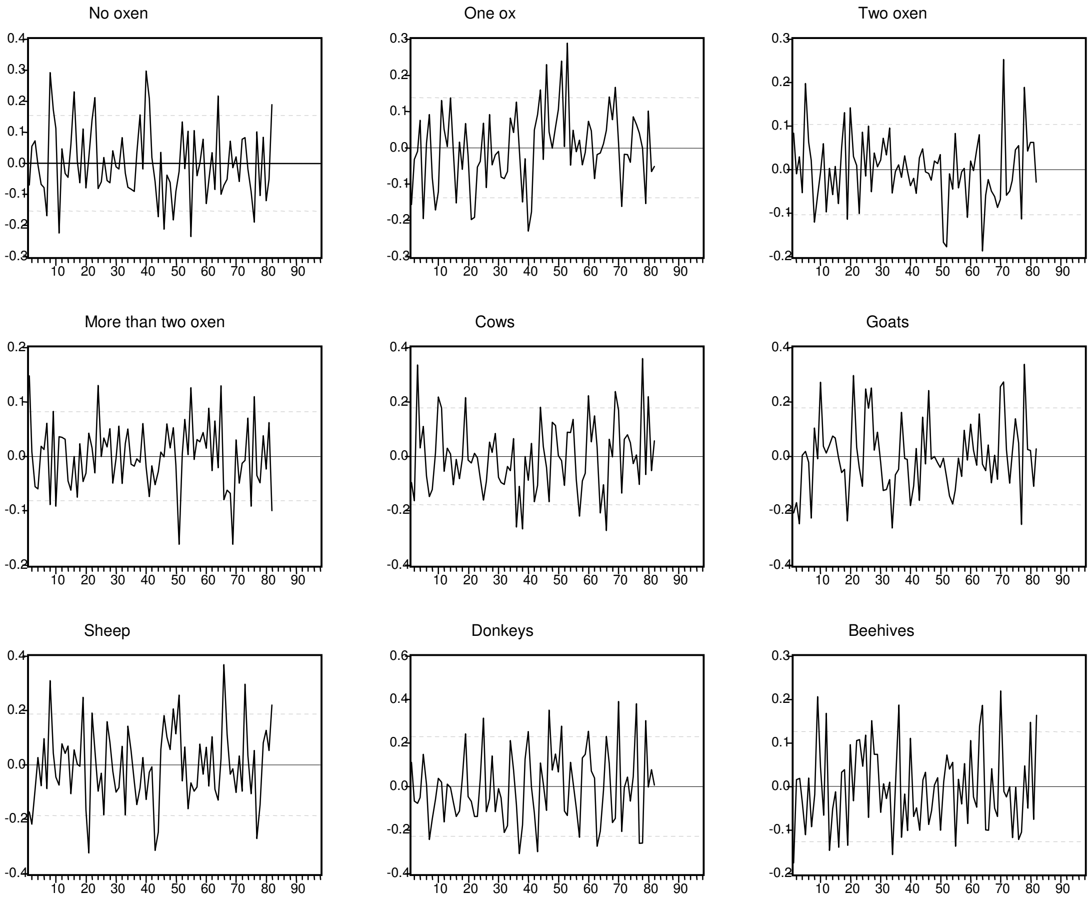

Figure 3 Residuals from third order polynomial estimation of proportion of farmers using livestock explained by development domain dimensions

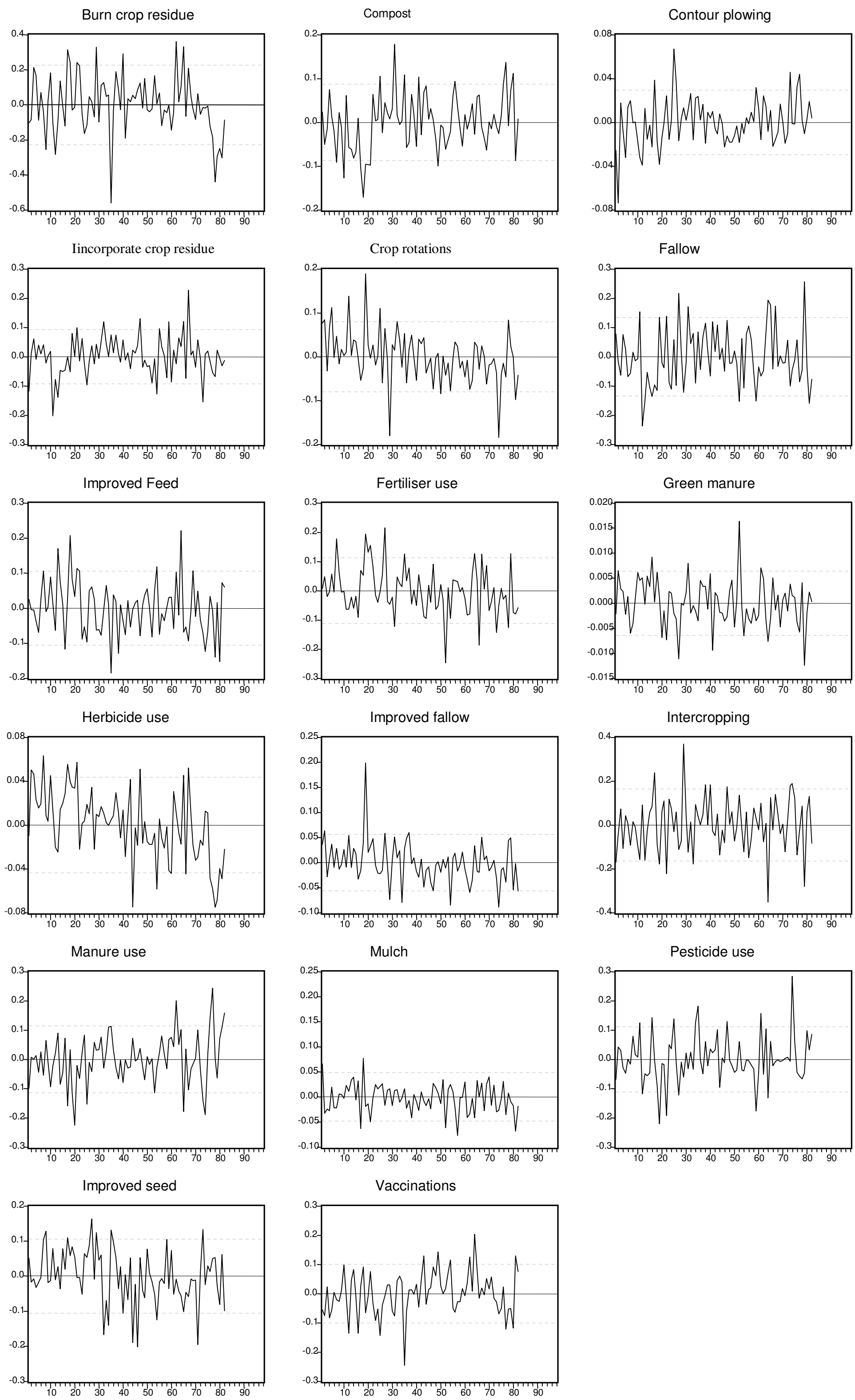

Figure 4 Residuals from third order polynomial estimation of proportion of farmers using technology explained by development domain dimensions (direct and indirect effects).

5 Conclusions

The direct and indirect effects of development domain dimensions are important in explaining many of the past investments, major cropping patterns, livestock use and technology choice. The diversity in these indicators found in Tigray can be explained to a large extent in this way. However part of the diversity is found in otherwise similar conditions. We explored to what extent this heterogeneity is related to the development domain dimensions and we find that a significant portion of the heterogeneity can be attributed to the development domain dimensions, albeit often in a complex way.

The policy implications of this analysis is that development domains do offer an important entree point for targeting interventions. We show that there is a linkage between investments, cropping patterns and technology choice. Institutional presence is very instrumental for investments that lie at the heart of changes in cropping patterns and technology choice. Patterns of crop diversification and the adoption of alternative technologies, both very instrumental in the alleviation of poverty and in ensuring sustainable livelihoods, are linked to development domains. Specific policy recommendations related to specific interventions in different domains are beyond the scope of the present paper, but will be feasible with some additional research based on this approach.

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