

**Explaining Agricultural Land Use in Villages
surrounding the Lore Lindu National Park in Central
Sulawesi, Indonesia**

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Summary

This paper examines the causes of agricultural land expansion using an analytical Chayanovian model. We estimate the model empirically for the Lore Lindu area. The results show a high elasticity of cultivated area with respect to population. Improved technologies, favourable natural characteristics and lower transaction costs have a direct negative and an indirect positive effect on agricultural land expansion. The direct effect is likely to dominate in the short run when population is fixed and labour markets are imperfect while the indirect effect relates more to the long run with labour being more mobile between sectors due to migration.

Keywords: Land use change, deforestation, agricultural land expansion, land use modelling, village survey, GIS data, Indonesia.

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1. Introduction

Deforestation and forest degradation have been mentioned to take alarming proportions with severe negative global and regional consequences such as global warming, loss in biodiversity, soil erosion, desertification, etc. To act upon this and design appropriate policies it is fundamental to understand what is driving this deforestation. Explaining deforestation has been the focus of an increasing number of theoretical as well as empirical studies. Further empirical research on this topic, especially quantitative micro-level analysis, is necessary (*Kaimowitz and Angelsen, 1998; Deininger and Minten, 1999*). Understanding the deforestation process is imperative for the case of Indonesia since the country holds a vital share of the world's remaining humid rainforest. Sulawesi is of particular interest because of its uniqueness in biodiversity that can only be sustained by preserving forest resources.

In this paper we investigate agricultural land use in the villages surrounding the Lore Lindu National Park in Central Sulawesi, Indonesia. The aim of the paper is to understand the causes of agricultural land expansion in this area. Indirectly, we hope to contribute to the empirical evidence on the driving forces of deforestation and hence to the general understanding of this process. We develop a formal theoretical approach to guide our empirical analysis. This is essential since the lack of an explicit theoretical framework can cause misspecification of empirical models and misinterpretation of the results—as in previous socio-economic land use studies (*Angelsen et al, 1999*).

After this introduction we start with a brief overview of the macroeconomic environment and the description of the situation in the Lore Lindu area. The next chapter comprehends the analytical model and a theoretical discussion of the causes of agricultural land expansion. The fourth chapter deals with issues for empirical estimation of the model. The regression results are given in chapter five. In the following chapter we discuss the results and compare them with findings from the literature. We spell out the policy implication of our findings in chapter seven. In chapter 8 we give some critical remarks concerning socio-economic land use modelling. A last chapter concludes.

2. The Setting

2.1. Increasing Agricultural Production and Decreasing Forest Resources

Indonesia with its 220 million inhabitants is the fifth most populated country in the world (*World Bank, 2001*). Nearly half of its population is living in rural areas and depends mainly on agriculture for their livelihood (*World Bank, 2001*). Although recently attention broadened towards improving rural incomes, for the last decades agrarian policies in the country have focused on increasing agricultural production. Both food self-sufficiency and growth of export oriented agricultural production have been main policy targets (*Thorbecke and van der Pluijm, 1993; Dirkse, 1993; Barbier, 1984*). Rice self sufficiency has been on the agenda since the start of the first 5 year plan in 1969 and was reached for the first time in 1984 (*Thorbecke and van der*

Pluijm, 1993). Over the past four decades paddy rice production increased from 12 to 51 thousand ton annually (Table 1). In the context of reducing the dependence on oil for export revenues after the oil shocks of the 1980's growth in export crop production became important. Table 1 shows that the production of the main export crops increased considerably. Indonesia is now the world's second largest producer of rubber (*Information Centre for Natural Rubber, 2002*); the third largest producer of cocoa (*International Cocoa Organisation, 2002*); and the fourth largest producer of coffee (*International Coffee Organisation, 2002*). Next to trade and price policies also rural policies such as the extension of the road network; the establishment of credit programs; increased investment in agricultural research combined with extension services; distribution of subsidized inputs etc. have supported this production growth. Despite increased yields per hectare stemming from technological progress, the growth in agricultural production has been associated with a vast expansion of the agricultural area (Table 1).

Table 1: Production and Area Harvested for Different Crops in Indonesia

	Production (1000 ton)			Area Harvested (1000 ha)		
	1961	1981	2001	1961	1981	2001
Paddy Rice	12.000	33.000	51.000	6.800	9.400	11.600
Coconut	5.600	9.320	17.000	1.130	1.890	2.800
Rubber	693	963	1.400	1.353	1.564	2.150
Coffee	103	315	390	182	527	981
Cocoa	1	13	340	7	23	360

Source: FAO

Indonesia has 60% of its total area under forest cover, representing 10% of all tropical forest in the world and nearly half of Asia's remaining rainforest (*FAO, 2002*). However, during the last decade 1.3 million hectares of forest or 1.17% disappeared annually (*FAO, 2002*). This is among the highest rates of deforestation in the world.

2.2. A Village Survey in the Lore Lindu Area

The Lore Lindu National Park is one of Indonesia's many protected areas. The Park covers some 220 thousand hectares of mountainous rainforest and is located in five districts in Central Sulawesi: Sigi Biromaru, Palolo, Kulawi, Lore Utara, and Lore Selatan. Of the 119 villages in these districts 60 have a border with and part of their administrative area inside the National Park. This area has been chosen as focus site for a collaborative research project funded by the German Research Council¹. The project's interdisciplinary research concerns the stability of rainforest marginal areas. Within this context we carry out a socio-economic study of land use change. For this study, 80 of the 119 villages have been selected for a village survey using a stratified random sampling method (for more details on the selection procedure see *Zeller et al, 2002*). The survey was conducted in the period March-July 2001. The survey data were complemented with socio-economic data from secondary sources and

geographical data combined in a geographical information system. The latter includes maps of administrative boundaries, road maps, and a digital elevation model with a resolution of 50 by 50 meters². With this combination of socio-economic survey data and geographical data we can overcome certain data limitation problems encountered in previous studies.

Deforestation and land use change have been studied at different levels. There are various household and regional level analysis as well as cross-country studies (for an overview of these studies see *Kaimowitz and Angelsen, 1998*). We take the village as unit of analysis because this allows us to assess the impact of factors such as population growth, which is difficult at the household level. Also, other factors influencing land use are often fixed at the village level; e.g. agricultural prices, the available technology etc.

2.3. A Description of the Area

The Natural Environment

The Lore Lindu area is situated in the humid tropics—around 1° south of the equator—and consists of mountain ranges reaching up to 2500 meters interspersed with narrow and outstretched valleys at different elevations. There is a lot of disparity in climate in this area with rainfall varying from 500 to 2500 mm annually. The borders of the 5 districts are set along mountain ranges which makes them have quite distinct natural features.

Demographic Characteristics

The region is demographically and culturally very diverse. Using the survey data, the actual population size was estimated at 132 thousand people and the overall population density at 18.69 per km² (Table 2). This is about 6 times lower than the Indonesian nation-wide population density of 116 per km² (*World Bank, 2001*). However, there is a huge variation in demographic characteristics across the districts. The northern districts, Sigi Biromaru and Palolo are quite densely populated; 86 and 43 people per km² respectively. In the rest of the region population density is much lower, around 10 people per km². Over the past 20 years, total population grew with 60%. In the Palolo and the Lore Utara district population more than doubled in this time span while in the other districts population growth was around 30 to 40%. Migration, planned migration as well as spontaneous migration, contributes significantly to these high growth rates. Overall, migrants, defined as coming from another province, account for 21% of the total number of households (Table 2). The Lore Utara district has the largest share of migrants; 30%. More than 11 thousand people moved to this area as part of local resettlement and transmigration programs. Especially the districts Palolo and Lore Utara received a lot of transmigrates; the latter since 1980, the former mainly during the 70's³ (Table 2).

The observed variation in demographic characteristics; the extent of demographic changes over the past two decades; and the important contribution of migration to these changes makes this area of particular interest for studying land use change. The role of population in driving deforestation has often been debated and forms a relevant question from a policy perspective. The research carried out in this demographically diverse area creates a good opportunity to investigate the link between population and agricultural land expansion.

Table 2: Demographic Characteristics per District

	Total	Sigi Biomaru	Palolo	Kulawi	Lore Utara	Lore Selatan
Total population 1980*	82.422	34.683	11.967	23.307	6.344	6.121
Total population 2001	132.214	50.392	24.392	31.726	16.899	8.011
<i>standard deviation</i>	6.292	5.058	1.870	2.281	2.270	394
Population density	18,69	86,49	42,96	10,35	7,95	10,90
Population growth 1980/2001	60%	45%	104%	36%	166%	31%
% migrants	21%	23%	23%	14%	30%	3%
<i>standard deviation</i>	1,97	4,15	4,00	1,77	5,67	0,20
# transmigrants before 1980**	6.151	1.347	4.804	0	0	0
# transmigrants since 1980**	5.092	0	2.294	0	2.798	0

Source: STORMA A3 village survey and secondary data

* Data source: Badan Pusat Statistik

** Data source: Departemen Transmigrasi, Department of social affairs, Forestry department, Badan Pembudayaan Masyarakat

Land Use and Agricultural Cultivation

Using data from a geographical information system we computed the total size of the research area to be slightly more than 700 thousand hectares (Table 3). From the survey data we estimated that 74 thousand hectares or 11% of this area is used for agricultural cultivation (Table 3). In the two most densely populated districts, Sigi Biomaru and Palolo, about one third of the total area is used for agriculture while in the other three districts this is less than 10% (Table 3). If the Park's area is excluded from calculation the share of the total area used for agriculture increases to 15% (Table 3). Only an insignificant amount of land—less than 1% of the total area—is specifically assigned for animal grazing. On that account and in accordance with the observation that livestock rearing is economically of little importance in this area, we limit ourselves to crop production in the discussion about agriculture and land use.

The most dominant crops in the area are paddy rice—the staple food crop—and perennial crops, mainly coffee and cocoa destined for export. Paddy rice fields account for one third of the total agricultural area and are prominent all over the region (figure 1). Of the 80 sampled villages, 13 are equipped with a technical irrigation system for paddy rice cultivation. This system allows farmers to harvest three times a year, two rice harvests and one intermediate harvest. In 25 villages paddy rice is cultivated with a system of semi-technical irrigation, allowing two rice harvests but no intermediate harvest. In the remaining villages they rely on a simple or rain-fed system for cultivating paddy rice (29 villages) or they have no paddy rice

fields at all (13 villages). Overall, perennial crops take about half of the agricultural area but they are especially important in the districts Palolo and Kulawi where the area under perennials is twice as large as the area allocated to paddy rice. The remaining 20% of the agricultural area are fields with annual crops—mainly upland rice and corn—and home-gardens where different crops are mixed (figure 1). Pesticides and chemical fertilisers are used in 95% respectively 73% of the villages. Apart from a medium sized government farm meant for research and one large commercial tea plantation, there are no large scale plantations in the area. All agricultural land, including cocoa and coffee plantations, are in the hands of small-holders. Expansion of small scale farming is the most important source of deforestation in Indonesia (*Sunderlin and Resosudarmo, 1996*). This justifies our approach of focussing on agricultural land expansion as an indirect way of explaining deforestation. Such an indirect approach was also applied by Angelsen et al (*1999*) and Barbier and Burgess (*1996*).

Table 3: Land Use per District

	Total	Sigi Biromaru	Palolo	Kulawi	Lore Utara	Lore Selatan
Total area	704.144	58.265	56.782	303.063	212.545	73.489
Total area outside TNLL	482.733	40.595	40.944	221.573	115.826	63.795
Agricultural area	<i>estimate</i> 74.168	19.379	16.880	23.898	11.609	2.401
<i>standard deviation_{sd}</i>	3.439	1.872	1.613	1.794	1.573	164
% of total area	11%	33%	30%	8%	5%	3%
% of total area outside TNLL	15%	48%	41%	11%	10%	4%
Area permanent pastures	<i>estimate</i> 5.831	420	798	497	3.974	143
<i>standard deviation_{sd}</i>	928	263	326	160	811	28
% of total area	0,83%	0,72%	1,41%	0,16%	1,87%	0,19%

Source: STORMA A3 village survey and GIS data

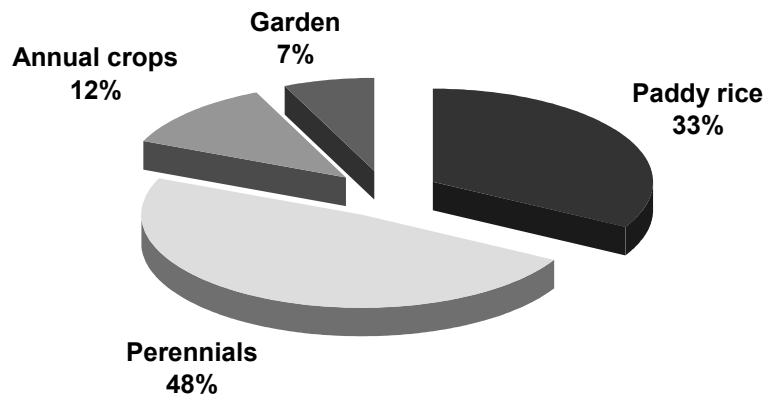


Figure 1: Allocation of the agricultural area to different crops (Source: STORMA A3 Village Survey)

Infrastructure and Markets

Two main asphalt roads connecting the villages with the provincial capital pass through the research area. In the Sigi Biromaru district the road network is more extensive and almost all villages are connected through asphalt roads. In the other districts there are gravel roads connecting the villages with the main road. However, one fourth of the sampled villages—mainly in Kulawi and Lore Selatan—is not accessible by car. Some of these villages or up to two or three days travelling—by foot or by horse—from the nearest asphalt road. The access to roads and the distance to output markets is important with respect to land use change since they determine transaction costs related to marketing of agricultural produce and hence local agricultural prices. Farm households are pretty well integrated in output markets; selling virtually their complete coffee and cocoa harvests. Also corn is mainly destined for the market and on average one third of the rice production is sold⁴.

87 % of the households are farmers. The remaining 13 % own small shops; are involved in trading activities; collect rattan; or are wage labourers- mainly government officials in the district capitals. Farming is the most important economic activity in the area and off-farm employment opportunities are quite limited. Although there is no real off-farm labour market, an agricultural labour market has developed, especially in areas with higher population density.

3. Theoretical Framework for Analysing Agricultural Land Use

Most analytical studies on agricultural land use and deforestation are based on either subsistence models or open-economy models (*Kaimowitz and Angelsen, 1998*). These two types of models differ a lot in the underlying assumptions and result in different explanations for agricultural land expansion (*Angelsen, 1995*). In subsistence models households are assumed to minimize labour to reach a predetermined level of consumption. Markets are assumed to be missing. Such models result in the ‘population approach’: population growth, a poor technology, bad soil characteristics etc. are considered as the major driving forces of deforestation. In open-economy models households are assumed to maximize profits facing a set of perfect markets. According to this approach -the ‘market approach’- the relative profitability of agriculture determines the area cultivated and deforested. Hence the two approaches lead to conflicting policy implications and are therefore extremely relevant. However, the assumptions on household behaviour and the functioning of markets, especially the labour market, in these models are rather unrealistic for the case of rural areas in developing countries. Therefore we use a Chayanovian model in which a representative household maximizes utility allowing for substitution between consumption and leisure. This is the standard formulation in the agricultural household literature (*Singh et al, 1986; Deaton, 1997; Udry, 1997*). An analytical approach using a Chayanovian type model was also developed by *Angelsen (1999)*. However, instead of considering the distance of the agricultural frontier from the village centre as in *Angelsen (1999)* we consider the total cultivated area. Our model further differs from the model in *Angelsen (1999)* in the specification of the production function and the assumptions about the functioning of the labour market.

3.1. The Framework

We assume a representative household in the village to maximize utility, a concave function of consumption and leisure; $U(c, l)$ with $U_{cl}; U_{lc} > 0$. The household is involved in agricultural production for which we assume a Cobb Douglas production function, f , with a productivity shifter. Labour, L , and land, A , are the factors of production. The marginal return to both factors is positive, $f_L; f_A > 0$ and decreasing, $f_{LL}; f_{AA} < 0$. The productivity shifter includes land suitability characteristics, S_1 , and the available technology, S_2 . The first factor reflects the natural suitability of the area for agricultural cultivation and includes aspects such as slope, altitude, climate, soil type etc. Better land characteristics and an improved technology increase output. This specification is more realistic than the linear production function with exogenously given yields used by *Angelsen (1999)*. Following von Thünen (*1966*) we assume an additional labour cost related to an increased walking time to the fields when more area is being cultivated and the distance from the village to the fields increases. We specify this cost as a convex function of the agricultural area, xA^t with $t > 1$. The labour market is assumed to be missing. Households depend completely on family labour and no off-farm employment is possible. We assume that the entire agricultural output is sold in the market at price p and that the resulting income is completely consumed. The household will decide how much land to cultivate and how to allocate

the total available time, T to leisure and agricultural production. This leads to the following optimisation problem:

$$\begin{aligned} & \text{Maximize } U(c, l) \\ & \text{With } c = pf(L, A) \quad \text{and} \quad f(L, A) = S_1 S_2 L^\alpha A^\beta \quad \text{with} \quad \begin{array}{l} 0 \leq \alpha; \beta \leq 1 \\ \alpha + \beta = 1 \end{array} \\ & \text{Subject to a time constraint: } T = L + l + xA^t \quad \text{with} \quad t > 1 \end{aligned}$$

The Lagrangian function of the maximization problem is

$$\psi = U(c, l) + \theta(T - L - l - xA^t)$$

leading to the following first order conditions:

$$\frac{\partial \Psi}{\partial l} = U_l - \theta = 0 \quad (1)$$

$$\frac{\partial \Psi}{\partial L} = U_c pf_L - \theta = 0 \quad (2)$$

$$\frac{\partial \Psi}{\partial A} = U_c pf_A - \theta t x A^{t-1} = 0 \quad (3)$$

From these three equations it follows that:

$$\theta = U_l = U_c pf_L \quad (4)$$

$$pf_L = \frac{pf_A}{t x A^{t-1}} \quad (5)$$

The Lagrange multiplier θ can be interpreted as the shadow wage (*Mas Colell et al, 1995*). Equation (4) expresses that the household will allocate its time in such a way that both marginal utility from leisure and marginal utility from labour in agriculture are equal to the shadow wage. Equation (5) expresses that land and labour will be used till the marginal return to those factors are equalized.

Considering that $f(L, A) = S_1 S_2 L^\alpha A^\beta$ it follows from equation (5) that:

$$L = \frac{\alpha}{\beta} t x A^t \quad (6)$$

Substituting θ with U_l and L with expression (6) in equation (3) and rearranging

$$\text{results in: } A = \left(\frac{U_c}{U_l} p S_1 S_2 \right)^X Y \quad \text{with} \quad Y = \left(\frac{\beta}{t x} \right)^{\frac{1}{t-1}} \alpha^{\frac{\alpha}{(1-\alpha)(t-1)}} > 0 \quad (7)$$

$$\text{and} \quad X = \frac{1}{t(1-\alpha) - \beta} = \frac{1}{(1-\alpha)(t-1)} > 0$$

Equations (6) and (7) along with the time constraint determine the amount of land the representative household will cultivate and how the available time will be allocated to labour and leisure.

Assuming that all households in the village have the same preferences we can aggregate equation (7) over all households in the village⁵ and obtain an expression for the total village agricultural area, A_{agr} :

$$A_{agr} = HA = H \left(\frac{U_c}{U_l} p S_1 S_2 \right)^X Y \quad (8)$$

with H the number of households in the village; and with X and Y as defined in equation (7).

3.2. The Effect of Exogenous Changes

Within this framework it is now possible to explain how exogenous changes in prices p and technology S_1 or differences in land suitability characteristics S_2 will affect the village agricultural area. Since $X > 0$, it follows directly from equation (8) that with an increase in agricultural prices, the cultivated area will increase. This is the so called ‘substitution effect’: when agriculture becomes more profitable households will substitute leisure for labour and increase the amount of land cultivated (*Van Rompuy et al, 1991; Kaimowitz and Angelsen, 1998; Angelsen, 1999*). However, there is a second effect that will dampen or even reverse this ‘substitution effect’. Due to higher agricultural prices, income and hence consumption will rise and will reduce the (absolute value of the) marginal rate of substitution between consumption and leisure, $|-U_c/U_l|$. According to equations (8) and (6) this causes a decrease in the agricultural area; a decrease in the labour allocated to agriculture; and an increase in the amount of leisure. This is the ‘income effect’: with increasing agricultural prices, income increases and households can reach a higher level of utility by increasing both consumption and leisure (*Van Rompuy et al, 1991; Kaimowitz and Angelsen, 1998; Angelsen, 1999*). So, the ultimate effect of the price increase on agricultural area depends on the form of the utility function.

We elucidated the effect for the case of a price increase but the same reasoning can be made for changes in S_1 or S_2 . Higher agricultural prices, a better technology and better land suitability characteristics will have a positive ‘substitution effect’ and a negative ‘income effect’ on the area cultivated.

3.4. The Effect of Population Growth

Population growth can affect agricultural land expansion in different ways. First, population growth can cause an immediate increase in the village agricultural area because of an increase in the number of households, which is clear from equation (8). Second, population growth can add to the household’s total available time, T ⁶. This will cause a decrease in the Lagrange multiplier or shadow wage, θ . Since $U_l = \theta$ and according to (8) this will cause an increase in the village agricultural area. If population growth lowers the shadow wage, the opportunity cost of labour decreases and hence more labour and land will be allocated to agriculture. Third, population growth can have an indirect or general equilibrium effect through an increase in local food prices.

3.5. The Form of the Utility Function

The effect of exogenous changes on the area cultivated depends on the form of the utility function; or more precisely on the marginal rate of substitution between consumption and leisure, $-U_c/U_l$. When people are poor and living close to subsistence levels of consumption, they are willing to give up a large amount of leisure in order to increase consumption. In this case, U_c/U_l will drop (rise) sharply with an increase (decrease) in consumption. This will cause the ‘income effect’ to prevail above the ‘substitution effect’ and the agricultural area will decrease with increasing agricultural prices, a better technology and better land characteristics. This is the same outcome as in the population approach using subsistence models. If consumption and leisure are perfect substitutes then $U_c/U_l = Cte$. In this extreme case, the ‘income effect’ will be zero and there is only a ‘substitution effect’ that causes the agricultural area to increase with increasing prices and productivity. This is the same result as in open-economy models. Leisure and consumption are more likely to be substitutes when labour markets are well functioning since labour can then be seen as any other consumption good. The final effect of exogenous changes depends on the marginal rate of substitution between consumption and leisure that on its turn depends on household’s preferences and the functioning of the labour market.

4. Empirical Model

The Empirical Model

The theoretical model outlined in the previous section resulted in an expression for the village agricultural area as a function of village population, agricultural prices, land suitability characteristics, agricultural technology, etc. Taking natural logarithms of equation (8) leads to the following:

$$\ln(A_{agr}) = \ln(H) + X \ln\left(\frac{U_c}{U_l}\right) + X \ln(p) + X \ln(S_1) + X \ln(S_2) + \ln(Y) \quad (9)$$

We assume that differences in village level agricultural prices are related to differences in transaction costs: $p = \gamma_0 Trans^{\gamma_1}$ with $\gamma_1 < 0$ indicating that prices decrease with increasing transaction costs (*von Thünen, 1966*). Substituting this expression for agricultural prices in equation (9); bringing together all constant terms; and combining unobservable household and village characteristics in an error term gives the following equation that can be estimated econometrically:

$$\ln(A_{agr}) = \alpha_0 + \alpha_1 \ln(H) + \alpha_3 \ln(Trans) + \alpha_4 \ln(S_1) + \alpha_5 \ln(S_2) + \alpha_6 u \quad (10)$$

Variables and Expected Effects

The variables included in the model are summarized in Table 4. The dependent variable, A_{agr_ln} is the natural logarithm of the actual village agricultural area. The first explanatory variable, Pop_ln is the natural logarithm of the village population. The transaction cost variable, $Trans$ is proxied by the time in hours needed to travel from the village centre to Palu, the main market⁷. The travel time ranges from 20 minutes to almost 18 hours. The level of agricultural technology, S_1 is included by a dummy variable, $Irrig$ indicating whether there is a technical irrigation system in the village covering at least half of the paddy rice area. A last set of

explanatory variables represents the land suitability characteristics, S_2 . From a digital elevation model we calculated for each village the average altitude, Alt_mean ; and the natural logarithm of the area outside the National Park with a slope lower than 3 degrees, A_flat_ln . Since villages at a higher elevation tend to be larger, we include the natural logarithm of the total village area, A_total_ln . Unfortunately we have no detailed data on climate and soil conditions. Since climate characteristics are peculiar for the different districts, we include district dummies to control for this. Soil conditions vary mainly with topographic characteristics, which we already allow for. In addition we include a dummy variable, $Badsoil$, that equals 1 if the village has more than 20 hectares *alang-alang*—a grass that grows on acid soils.

Table 4: Overview of Variables in the Model

Variable	Name	Mean	Std. Dev.	Min	Max
Agricultural area (ha)	A_agr	605	465	52	2.147
ln (Agricultural area)	A_agr_ln	6,08	0,88	3,95	7,67
Population	Pop	1.120	875	235	4.676
ln (Population)	Pop_ln	6,78	0,69	5,46	8,45
Travel time to market (hours)	Trans	5,31	4,93	0,25	17,76
ln (Travel time to market)	Trans_ln	1,22	1,00	-1,39	2,88
Dummy technology level	Tech	0,13	0,33	0	1
Flat area (ha)	A_flat	630	856	11	4.284
ln (Flat area)	A_flat_ln	5,56	1,47	2,40	8,36
Average altitude	Alt_mean	856	430	46	1.716
Dummy bad soils	Badsoil	0,24	0,43	0	1
Total area (ha)	A_total	5.361	4.144	330	22.027
ln (Total Area)	A_total_ln	8,24	0,92	5,80	10,00
Dummy Sigi Biromaru	kec_sigi	0,19	0,39	0	1
Dummy Palolo	kec_palo	0,18	0,38	0	1
Dummy Lore Utara	kec_loru	0,18	0,38	0	1
Dummy Lore Selatan	kec_lors	0,14	0,35	0	1

Source: STORMA A3 village survey and GIS data

In Table 5 we give an overview of the theoretical outcome, distinguishing between the income and the substitution effect. Population is expected to have a general positive effect on agricultural land use. Travel time to the market, average village altitude, and the dummy variable for bad soils have a positive income effect and a negative substitution effect. The amount of flat area and the dummy for technology level have a negative income effect and a positive substitution effect.

Table 5: Expected Effects on Agricultural Land Use

Explanatory Variables	Income effect	Substitution effect	General effect
Population			+
Travel time to the market	+	-	
Technology level	-	+	
Flat area	-	+	
Average elevation	+	+	
Bad soil	+	-	

Issues for Empirical Estimation

We estimate equation (10) using OLS. One of the 80 observations is dropped due to missing values. The Variance Inflation Factors indicate that there is no problem of multicollinearity. Using the Breusch-Pagan test the homoskedasticity-hypothesis could not be rejected at the 1% significance level.

Population can not be treated as endogenous in our model. Population levels are likely to be higher in areas that are more suited for agricultural cultivation or where market access is better. Population and agricultural land use are likely to be influenced by the same set of explanatory variables and would be jointly determined or be interdependent. Statistically, we deal with this problem using instrumental variable estimation. As instruments for population we use the following variables: the number of years certain facilities –pumped or piped water, electricity, a doctor, and a junior high school- are in the village and the year the village was established. These variables are highly correlated with population and have no direct impact on agricultural land use. The endogenous character of population calls for caution in the interpretation of the results.

District dummies were included in the model to control for differences in climate. However, these dummies encompass variability in other factor as well, e.g. travel time to the market. Therefore we estimate the model with and without these district dummies. We have three different regression specifications (Table 6). Specification 1 is the OLS regression with district dummies. Specification 2 is the IV regression with district dummies and specification 3 is the IV regression without district dummies.

5. Results

The regression results are reported in Table 6. The overall performance of the model is quite good with an adjusted R^2 between 0.66 and 0.54 for the different estimations. In all three specifications, the ‘all-coefficients-zero’-hypothesis can be rejected at the 1% significance level. The estimated coefficients in specification 1 are not much different than those in specification 2, which is an indication of the robustness of the results.

We find a positive effect of population on agricultural land use. The effect is highly significant in all three specifications. Regression specification 1 and 2 show a significant positive effect of the variable travel time to the market. When transaction

costs are high and local agricultural prices low, more area is taken into cultivation. The access to a technical irrigation system significantly reduces the agricultural area. However, the coefficient is significant only when districts dummies are omitted. This follows from the fact that only in 2 districts, Sigi Biromaru and Kulawi, there are villages with a technical irrigation system. The variables indicating the natural suitability of the land for agricultural cultivation all have a significant effect. The amount of flat land has a negative impact on agricultural land use but is more determinative across the districts than within. The average altitude and the indicator for bad soil conditions have a significant positive effect and are more important within the districts. This indicates that less area is taken into cultivation where natural characteristics are better. Also the significant negative effect of the district dummies for Lore Utara and Lore Selatan, where rainfall is higher, point to that. Comparing the regression results with what was predicted from theory (Table 5) indicates that the 'income effect' of household behaviour prevails above the 'substitution effect'.

Table 6: Regression Results

	Specification 1				Specification 2				Specification 3			
	OLS Estimation				IV Estimation				IV Estimation			
Number of obs	79				79				79			
F(11, 67)	14,90				9,43				7,60			
Prob > F	0,0000				0,0000				0,0000			
R-squared	0,7098				0,7068				0,5843			
Adj R-squared	0,6622				0,6586				0,5433			
Root MSE	0,5103				0,5130				0,5933			
A_agr_ln	Coef.	Std. Err.	t	P> t	Coef.	Std. Err.	t	P> t	Coef.	Std. Err.	t	P> t
Pop_ln	1,0260	0,1128	9,10	0,000	0,9310	0,1926	4,83	0,000	1,0789	0,2165	4,98	0,000
Trans_ln	0,2532	0,1291	1,96	0,054	0,2400	0,1315	1,82	0,073	-0,1066	0,1134	-0,94	0,351
Tech	-0,2706	0,2363	-1,15	0,256	-0,2398	0,2428	-0,99	0,327	-0,4501	0,2540	-1,77	0,081
A_flat_ln	-0,0299	0,0496	-0,60	0,548	-0,0204	0,0522	-0,39	0,698	-0,0889	0,0537	-1,66	0,102
Alt_mean	0,0007	0,0003	2,41	0,019	0,0007	0,0003	2,33	0,023	0,0002	0,0003	0,63	0,533
Badsoil	0,3357	0,1593	2,11	0,039	0,3173	0,1630	1,95	0,056	0,0668	0,1796	0,37	0,711
A_total_ln	-0,0215	0,0907	-0,24	0,814	-0,0185	0,0913	-0,20	0,840	0,1498	0,0964	1,55	0,125
kec_sigi	0,6169	0,3127	1,97	0,053	0,6320	0,3154	2,00	0,049	-1,9486	1,5868	-1,23	0,224
kec_palo	0,2134	0,2333	0,91	0,364	0,2336	0,2369	0,99	0,328				
kec_loru	-0,5345	0,2219	-2,41	0,019	-0,5509	0,2247	-2,45	0,017				
kec_lors	-1,3434	0,2600	-5,17	0,000	-1,3606	0,2629	-5,18	0,000				
cons	-1,3951	0,9889	-1,41	0,163	-0,7974	1,3958	-0,57	0,570	-1,5295	1,5880	-0,96	0,339

Source: STORMA A3 village survey and GIS data

6. Discussion

Population

Since the regression is specified log-log for the variable population, the coefficient can be interpreted as the elasticity of the cultivated area with respect to population. This elasticity is 0.93 meaning that a 1% increase in population leads to a 0.93% increase in area cultivated (Table 6, specification 2). There is a lot of evidence of a high correlation between population and agricultural expansion or forest cover loss from studies at different levels of aggregation. Barbier and Burgess (1997) made a cross-country study including 53 tropical countries. They find that a 1% increase in population causes a 0.03% increase in forest clearing over the period 1980-85. In a regional level panel study on agricultural land expansion in Tanzania Angelsen et al. (1999) find an elasticity of agricultural area with respect to population of 0.6. Barbier and Burgess (1996) did a state level analysis in Mexico and find an elasticity of 0.23. Compared to these figures, the elasticity of agricultural area with respect to population that we find for the Lore Lindu area is quite high. This is due to the difference in aggregation level. Our study is limited to a relatively small rural area while regional or provincial level studies incorporate also urban centres where population growth is high but does not contribute to land expansion. The high positive effect of population on agricultural land use is also related to the fact that land is still fairly abundant in the Lore Lindu area.

Despite the evidence, the role of population in driving agricultural land expansion and deforestation is much debated in the literature. It is argued that high correlations between population and forest cover loss might be incidental rather than causal or might be spurious due to aggregation bias in the data and failure to account for other unobserved effects (Sunderlin and Resosudarmo, 1996; Deinginer and Minten, 1999; Angelsen et al, 1999).

Technology

Our results show that an improved agricultural technology, namely a better irrigation system, reduces the area cultivated. This is in line with results from previous empirical studies. Deininger and Minten (1999) find that irrigation and access to extension services has significantly reduced deforestation in the 1980's for Mexican municipalities. Mertens et al (2000) show that increased use of chemical inputs has cut down deforestation in the period 1986-1996 for villages in South Cameroon. Shively and Martinez (2001) did a farm level study in 2 communities in Southern Palawan and observe that the establishment of irrigation has reduced annual forest clearing with 48%. However, there are also studies that point to an opposite result. In a study on Tanzania Angelsen et al (1999) demonstrate a positive association between per capita fertilizer use and agricultural expansion.

Distance to markets and natural land characteristics

We find that distance to the market is positively related with agricultural expansion. There are two aspects related to this observation because increased transaction costs lower local agricultural prices and raise input prices. First, the observed effect indicates that farmers compensate for a lower profitability of farming by taking more area into cultivation. This is in line with the observed high 'income effect' of household behaviour. Second, lower input prices induce a more capital intensive method of cultivation and reduce agricultural expansion. This is supported by the

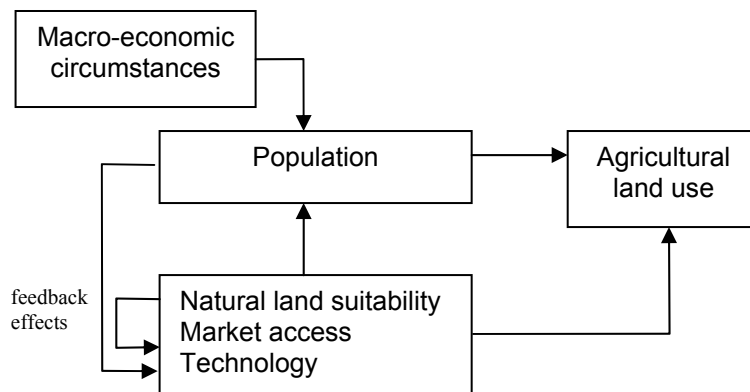
following observation. We classified the villages in travel time terciles and calculated that chemical fertilizers are used in 100% of the villages close to the market; in 92% of the villages further from the market and in 30% of the villages far from the market. Our results demonstrate that agricultural land expansion is positively related with distance to the market and negatively related with the natural suitability of land for cultivation. These effects are opposite to what is mostly found in the literature. Physio-geographic land characteristics and plot level indicators for distances to villages and markets are among the main explanatory variables in spatial land use models. The results from such studies show that the probability of agricultural land use or deforestation is higher if land suitability characteristics are better and access to the market is better. However, in those studies population is measured at a much larger scale –district or regional level- than the other variables in the model –plot or pixel level (e.g. in Cropper *et al*, 2001; and Deininger and Minten, 2001) or is omitted at all (e.g. in Nelson *et al*, 2001; Nelsen and Hellerstein, 1997; and Chomitz and Gray, 1996). The results from these spatial models are supported by evidence from some non-spatial empirical studies. Deininger and Minten (1999) find that natural land suitability and marketing infrastructure is positively respectively negatively related with deforestation at the municipality level in Mexico. They do not take into account population in the analysis. In a farm level analysis of settler households in the Brazilian Amazon Pichon (1997) indicates that higher land fertility and better market access results in more forest clearing. Regional and village level studies that do account for demographic characteristics come to different results. Barbier and Burgess (1996) show that road density has no significant effect on expansion of the agricultural area in a state level analysis in Mexico. In a village level analysis of deforestation in South Cameroon Mertens *et al* (2001) demonstrate that distance to the market significantly increases deforestation. The latter is the same result as we find for the Lore Lindu area.

There is not much evidence from land use studies explicitly including natural land characteristics that supports our observed results. Along with the applied technology, natural land characteristics largely determine agricultural yields. Therefore measuring the effect of higher yields on agricultural land use can be seen as an indirect way of assessing the impact of natural land characteristics. Barbier and Burgess (1997) show a negative association between forest conversion and yields in a cross-country study. Godoy *et al* (1997) find the same result at the household level for Honduras. This is in line with our findings that better land characteristics and hence higher yields lead to less agricultural land expansion.

There is no consensus on how market access and natural land characteristics influence land use. The outcome of empirical land use studies seems to depend a lot on the selection of explanatory variables and the scale at which those are measured.

Short term versus long term effects

From theory it follows that population, market access, technology and physio-geographic land characteristics influence agricultural land use. Taking into account the endogenous character of population, we arrive at a causal framework as depicted in figure 2. In what follows we elucidate the relationships in figure 2. The framework allows us to explain why some of our results deviate from what has been observed in other studies; and clarify a bit of the confusion about cause-effect relationships that exist in the literature.

Figure 2: Conceptual Framework

First; technology, market access and land characteristics have a direct impact on agricultural land use. We estimated this impact to be negative for the case of the Lore Lindu area: improved technology, lower travel time to the market, and better land characteristics have a direct negative impact on agricultural land use. Second, market access and land characteristics—and to a lesser extent also technology—are important determinants of population levels since a high (expected) productivity and profitability of agricultural cultivation is a pull factor in the rural-to-rural migration process. In our sample, village population density is negatively correlated with travel time to the market ($R=0.41$); positively correlated with the percentage of flat land in the village ($R=0.58$); and negatively correlated with the average village elevation ($R=0.75$). In addition, push factors are important in the rural migration process and hence local population levels are also influenced by the rest of the economy. Third, population influences land use. Theory as well as empirical evidence—from our study as well as from many others—indicate that a higher population increases the area cultivated. Hence, market access and land characteristics have an indirect impact on land use. A better accessibility and favourable natural conditions increase population and consequently the area cultivated.

The distinction between direct effects (lower left part of figure 2) and indirect effects (upper right part of figure 2) can be related to the time horizon of analysis and to the assumptions in different theoretical models. The direct effect is likely to dominate in the short run while the indirect effect relates more to the long run. In the short term population is fixed and labour markets are imperfect due to labour being immobile between sectors. In the long term, labour markets function better because migration makes labour mobile. The difference between the subsistence and the open economy approaches is also a reflection of the time horizon: the open economy model with perfect labour markets is more relevant for the study of long term effects (*Angelsen, 1995*). To give appropriate policy recommendations it is imperative to understand both, short term and long term effects.

Our results deviate from other results in the literature as regards the direction of the impact of market access and land characteristics on land use. There are two explanations for this (apparent) contradiction. First, the negative impact we find is caused by a high ‘income effect’ of household behaviour, which is a result of subsistence oriented household preferences and/or missing off-farm labour markets

(see chapter 8). However, it might be that in other areas with better functioning labour markets and/or higher income levels the ‘substitution effect’ prevails above the ‘income effect’ and that consequently market access and favourable natural characteristics have a direct positive impact on agricultural land use, even in the short run. Second, by omitting population as an explanatory variable from empirical land use models, the direct short term effects and the long term indirect effects are merged. This is what is mostly done in spatial land use models. This approach is valid if the purpose is to estimate where deforestation is likely to occur (e.g. for spatial planning or selection of areas to be protected) (*Kaimowitz and Angelsen, 1998; Lambin, 1994*) but it contributes little to the insight why deforestation is taking place.

Finally, we explain the feedback effects in figure 2. The placement of roads and other government infrastructure projects is not random but likely to be influenced by demographic and physio-geographic characteristics (*Pitt et al, 1993*). From the induced innovation literature we know that technological change can be induced by changes in relative prices, population growth, etc. (*Ruttan, 1986*). All this causes feedback effects between population, market access and technology. We were unable to consider these effects in our cross-sectional analysis of land use. An important drawback of this is that we only included one indicator for technology–technical irrigation–in our analysis. The infrastructure for technical irrigation is built by the government in special irrigation projects for which the placement depends a lot on the geographical location with respect to rivers. The presence of a technical irrigation system could therefore (to some extent) be considered as exogenous in our land use model. The impact of other technologies such as chemical inputs, mechanization, etc. on land use should be studied in a dynamic framework.

7. Policy Implications

The population approach, resulting from subsistence models, considers technological improvement and control of population levels to be key in preventing further deforestation (*Angelsen et al, 1999*). Open economy models and the market approach, on the other hand, emphasize the importance of economic development outside the agricultural sector and point to the counter-productive effect of agricultural intensification on deforestation (*Angelsen et al, 1999*). The intermediate approach we applied and the results from our empirical analysis imply a deliberate mixture of those strategies.

The very high elasticity of agriculture land use with respect to population calls for control of population growth in remaining forested areas. Attention should be put towards the broader economy for creating better economic opportunities and alternative employment, especially in areas characterized by heavy emigration and so attenuate the push factors for rural migration.

Our results indicate that higher transaction costs lead to more agricultural land expansion. Extension of the road network would reduce transaction costs but would lead to population growth since newly accessible areas are attractive for migrants. As suggested by others (e.g. *Barbier and Burgess, 1996; Southgate et al, 1991; Pichon, 1997; and Angelsen, 1999*); rather than extending the road network with new roads into forested areas, the density and quality of the existing road network should be

improved. This would reduce pressure on forests by lowering transaction costs in already populated areas. At the same time, this could benefit rural incomes and reduce poverty.

Contrarily to what the market approach reasons, our results indicate that there is a potential for reducing deforestation by improving agricultural technology. Especially the establishment of irrigation systems could benefit the environment in the Lore Lindu area. Since technical improvement increases productivity, there could be a win-win situation for reaching environmental goals and economic growth.

Areas where the environment is less suited for agricultural production are less populated but unfavourable natural conditions cause agricultural land expansion because farmers compensate for a lower productivity by taking more land into cultivation. This observation makes land use planning with zoning and control of human settlement a rational policy from an environmental perspective. In addition, establishment of protected areas with entry restrictions could limit immigration and indirectly reduce pressure on forests.

8. Socio-Economic Land Use Modelling

In the theoretical discussion it was argued that the final effect of exogenous changes on agricultural land use depends on the marginal rate of substitution between consumption and leisure, which depends on households preferences and the functioning of the labour market. Our results indicate that the 'income effect' of household behaviour prevails above the 'substitution effect', especially in the short run. This could mean that households in this area are living close to subsistence levels of consumption or that they have high preferences towards leisure and are not really interested in increasing consumption above subsistence needs. However, we feel like this is both very unlikely. First, although there is poverty in this area, the problem is not that severe that it would completely determine our results. Second, farmers in the area are very well integrated in output markets and can trade their agricultural produce for other consumption goods, which makes subsistence type preferences very doubtful. The large 'income effect' observed is more likely to be the result of thin or missing off-farm labour markets.

Assumptions about the functioning of the labour market are crucial in the way theoretical models predict how exogenous changes will affect land use. The justification to use analytical open-economy models in which households act as profit maximizing agents to guide policies is often based on the observation that households are increasingly integrated in output markets and have increasing cash requirements (*Angelsen, 1995*). However, with thin or non-existing rural labour markets households' consumption and production decisions are not separable and households cannot be assumed to act as profit maximizing agents even if they can freely trade agricultural products for consumption goods (*Udry, 1997*). Since open-economy models based on the assumption of perfect labor markets result in completely different, even opposite, policy implication than subsistence or intermediate models, one should be cautious with using such analytical argumentation without empirical evidence. We feel that Chayanovian models are better suited for analytical analysis of

land use changes, especially when it concerns rural areas of developing countries where labour market are often highly imperfect.

9. Conclusion

The main purpose of this paper has been to explain agricultural land expansion in the area surrounding the Lore Lindu National Park. To guide the specification of an empirical model and the interpretation of the results we developed an analytical approach using a Chayanovian type model. According to this model, the way exogenous factors affect land use depends on household preferences and the functioning of the labour market. We estimated the model empirically using socio-economic data from a village survey and geographical data combined in a GIS. The results of the empirical analysis indicate that the elasticity of the cultivated area with respect to population is rather high in this area. This has its cause in the fact that land is still quite abundant and in a low off-farm absorption of the rural labour force. Further, we find that there is a direct and an indirect effect of exogenous changes. An improved agricultural technology, favourable land characteristics and lower transaction costs have a direct negative impact on agricultural land expansion. Indirectly however, these aspects might be pull-factors in the rural migration process and cause local population to increase, which has a land expansionary effect. The direct effect is likely to dominate in the short run while the indirect effect relates more to the long run. In the short term population is fixed and labour markets are imperfect due to labour being immobile between sectors. In the long term, labour markets function better because migration makes labour mobile. The time horizon reflects the differences between the 'population approach' and the 'market approach', the two approaches discussed in the literature on the driving forces of land use change.

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² The digital elevation model was constructed using 1:25,000 scale topographic maps from Bakosurtanal.

³ Out-migration is not significant in this area. We estimated that over the last 20 years 1381 people migrated out of the area, which is 1.6% of the total 1980 population.

⁴ This figure has to be interpreted with care. It is often the case that farmers sell part of their rice harvest to fulfil immediate cash requirements but later they are forced to buy rice at market prices.

⁵ Aggregation of the behaviour of a representative agent is a valuable way to include microeconomic behaviour into aggregate issues (Deaton, 1992).

⁶ This can happen either through a direct increase in the household’s labour force or indirectly through the agricultural labour market for which wages are endogenous.

⁷ The travel time to the market was calculated as follows: distance on asphalt road*30km/hour + distance on gravel or dirt road*10 km/hour + walking distance*3km/hour. The distances were calculated using GIS. The calculated travel time variable corresponds very well to reality, as revealed from our own experiences in the field.