Spatial Mismatch Between Population Density and Land Potential: The Case of Zimbabwe

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Résumé: *La question de la sécurité alimentaire durable au Zimbabwe est confrontée à la concurrence pour obtenir des terres arables menée entre le secteur des grandes entreprises agricoles commerciales et celui des petits exploitants se livrant à la production vivrière pour l'auto-consommation. Or, les politiques agricoles coloniales et post-coloniales ont toujours privilégié les grandes entreprises agricoles commerciales qui occupent les terres, dotées du meilleur potentiel et à faible densité de population. Le secteur des petites exploitations agricoles, par contre, dispose non seulement des terres les plus mauvaises pour l'agriculture, mais des terres à forte densité de population. L'inadéquation spatiale entre la densité de population et le potentiel de terres, qui en résulte, a finalement donné lieu à une situation difficile sur le plan écologique. Cet article procède à une analyse à partir des données relatives à l'utilisation des terres par le secteur agricole communautaire petites exploitations et le secteur agricole commercial des grandes exploitations au Zimbabwe.*

Introduction

A crucial factor in sub-Saharan Africa's (SSA) food security problem is the spatial mismatch between population density and quality of arable land. Spatial mismatch refers to a situation within a nation in which land with superior potential is comparatively sparsely populated whereas land of deficient potential is inhabited with high densities of population. In many countries of SSA, large portions of the subsistence households live in relatively high density settlements on land of deficient and/or declining potential. At the same time, lands of higher potential exist with sparse populations and/or are reserved for commercial use and/or national parks. The purpose of this paper is to demonstrate, using the well-documented case of Zimbabwe's rural land distribution, the significance of studies in spatial mismatch in order to deal with issues of food security and sustainability in rural enterprises. The paper is also meant to highlight the importance of detailed small-area analysis for detection of the environmental stability of lands that are being worked by small-holder operators. A cursory look at this problem indicates that because of spatial mismatch, land-rich countries such as Zimbabwe, Sudan, Ethiopia and Tanzania face immense problems from environmental damage in areas inhabited by small-holder operators. The situation is aggravated by the fact that these lands are often of

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low potential to begin with and have been settled at high densities for too long (Mascarenhas 1983; Cleaver and Schreiber 1991:160; Lele and Stone 1989:22; Moore 1993).

Two principal causal factors have been responsible for most spatial mismatch between population and land resources in SSA. The first includes ecological and cultural phenomena which influenced traditional settlements which were voluntarily established in relatively open land frontiers in precolonial Africa. In some cases, ecological phenomena such as tropical diseases (malaria, schistosomiasis and river blindness) caused rural people to avoid more fertile low-lying lands, river valleys and alluvial plains in preference for higher, safer and dryer but less endowed areas (Hunter 1977, Benoit 1974, Stamp and Morgan 1972:349-51; Whitsun foundation 1980, 21-22). In other cases, cultural and political factors, which have their origin in defence against enemies or in insuring agroecological suitability for traditional staple varieties and livestock stewardship, have restricted high-density settlements (Wolde-Mariam 1972, 1992:49-55).

The second and perhaps more important factor of spatial mismatch had to do with colonial and post-colonial structures which gave rise to artificial closure of land frontiers for small holder agriculture limiting it to marginal lands of inferior use capacity (Heyer 1981; Denoon 1983; Thompson 1991). In various SSA countries, post-colonial agribusiness schemes, often in association with parastatal agencies, have also resulted in large scale appropriation and consolidation of high-potential lands for use in commercial estates thereby causing increased pressure on fragile lands by small-holder food producers (Heyer et al. 1981; Prothero 1972; Kitching 1980; Thompson 1991; Richter 1988).

Spatial Mismatch and Food Security Concerns in SSA

The impact of spatial mismatch on food security and overall rural development in SSA depends on current population/land balances. In land-poor countries such as Kenya, Rwanda, Burundi, Lesotho and Malawi, spatial mismatch is relatively less prominent as overall rural densities of population are high and generally congruent with location of high potential land (Lele and Stone 1989:22; Cleaver and Schreiber 1991:160). This is indicated by a high land-use index which is the per cent of arable land under annual and permanent crops of total potential arable land in the country. The indices for Lesotho, Rwanda and Kenya are 100, 85 and 64 percent respectively (100 percent signifying use of all arable land in the country) (FAO 1986b:53; World Bank 1991:204). In such cases, little improvement in agricultural output can be expected from increased acreage under crops as land reserves are either depleted or likely to be of very marginal quality (Kitching 1980; Lele and Stone 1989). In land-poor countries, raising the level of food security and rural productivity in general will have to depend on policy options that include technological intensification of agriculture, urban development, food imports and population planning (Lele and Stone 1989:22; Shipton 1987).

In countries such as Tanzania and Zimbabwe, land-use indices are much lower: 25 and 26 percent respectively (FAO 1986b, 53) but there is a high degree of spatial mismatch. In these countries, a large segment of the rural population resides in poorly endowed or depleted regions at very high population densities while better endowed lands exist with much lower population densities (Kay 1970). In relatively land-rich and high-spatial mismatch cases such as these, increased food security for small-holder farmers may have to depend largely on increments in acreage under small holder farms. First, reserves of land in these countries are better in quality than most currently settled lands. Second, high population pressure on small-holder agriculture has caused increased damage of land resources. For example, in Tanzania, small-holder farmers are concentrated in the Lake Victoria Basin, the Dodoma region and the Northeastern Highlands. Land degradation is a major problem in these areas (Kauzeni *et al.*, 1987; Boesen 1986). Lands with high potential and lower population density are found in the Southern Highlands of Tanzania. In Zimbabwe, where rural land is divided in two distinct communal and commercial zones, land potential in the small holder communal sector is very low and increasingly degraded under some of the highest rural population densities in Africa (Davies and Wheeler 1985; Nyamapfene 1990; Elwell 1985; Whitlow 1980, 1988a). On the other hand, large amounts of land with superior potential exist in half of the country with very low population density (Moyo 1986).

Although concerns on food security for SSA's rural populations have been expressed from a variety of perspectives, (World Bank 1988; OTA 1988:3-9; FAO 1986a; Thompson 1991:5-30), most blame was put on the general shortcomings of tropical Africa's land endowments and rapidly rising populations (Kamarck 1976; FAO 1986a:1-4; OTA 1988:9; Cleaver and Schreiber 1991; Salih 93:2-5). Few studies offer important details on microregional variations in land use stress and how much of this variation is explained by localised spatial mismatch (Lele and Stone 1989:12-25; Rukuni 1990:4-10). The purpose of this paper is to contribute to this type of research by using the case of Zimbabwe as an illustrative example in which spatial mismatch has been a major factor in rural poverty and environmental degradation.

The Ecopolitics of Spatial Mismatch

Spatial mismatch between population and land of good potential in SSA has been mostly the result of colonial acts on land apportionment which began essentially with the establishment of a dual economy in the early part of this century. Rural land in almost all African countries has been divided between small-holder communal (subsistence) sector and large-holder commercial (private estate) sector. The allocation measures and subsequent patterns of land tenure have caused a sharp competition for arable land between small-holder communal farmers and large-scale commercial plantations.

Generally, there have been three historical developments that gave rise to this competition: (1) reduction of acreage in the communal sector while increasing the acreage of the commercial sector, and (2) concentration of low potential land in the subsistence domain while reserving high potential land for commercial purposes, and (3) creation of high-density labour pools in small-holder communal lands while maintaining low-densities in the commercial domain (Heyer 1981; Kay 1975; Arrighi 1970; Moore 1993). Almost invariably, this produced declining food yields, population pressure and environmental degradation in the small-holder sector. This gave rise to a new approach in the study of rural development called ecopolitical economy theory which argued that benefits accruing to large scale plantations, which were developed at the expense of small holder acreage, rarely benefited the small holder and often they were also environmentally unsound developments (Yapa 1980, 1993; Moore 1993).

The ecopolitical economy of rural Zimbabwe, and resultant spatial mismatch, were typical of colonial and postcolonial developments in the eastern and southern parts of Africa. These included the restriction of population influx between legally delineated communal small-holder domain and commercial large-scale agriculture areas (Nyamapfene 1990; Myers and Ames 1984; Whitsun 1980; Palmer 1977; Riddel 1978; Moyo 1986), the truncation of small-holder agriculture from national market channels (Barnes and Clatworthy 1976; Mhlanga 1982; Whitsun 1981), and the poor diffusion of technological innovations between technology-poor communal lands and technology-rich commercial sectors (Rukuni 1990; Dankwerts 1976; Mutambirwa 1990; Reid 1976; Whitsun 1980; Norman 1986). Although the historical specifics may vary, similar conditions have prevailed in many SSA nations producing various degrees of spatial mismatch with communal small-holders too isolated and too poor in land potential to make high-density settlements economically viable. On the contrary, the outcome has been chronic food deficit and environmental degradation. The rationale for widespread analysis of spatial mismatch in SSA countries is derived from this imperative.

Analysing Spatial Mismatch

Planning for sustainable agricultural development in SSA should be preceded by detailed country studies of spatial mismatch based on small-area data. Small-areas — the smallest administrative units or census enumeration areas, whichever is smaller, for which census or other survey data on population and land are available. The smaller the area, the better is the resolution on the detection of localised spatial mismatch. Because of its excellent data base in statistical reports, maps and census figures, and the availability of census data by district level enumeration areas, the case of Zimbabwe is used to demonstrate procedures of data processing to gauge spatial mismatch and to learn some lessons on the deleterious impacts of spatial mismatch.

Preparing the Data Matrices

Analysis of spatial mismatch calls for the compilation of data on population and land area in the form of bivariate distributional matrices with variations in population density on one vector and land use potential on the other. These schedules should be prepared for as many major national land use categories as are present in significant magnitudes. In the case of Zimbabwe, until recently, two principal categories of rural land use, commonly referred to as communal land and commercial land, have been dominant. The variables used for the compilation of the matrix are population density classes scaled from low to high density on rows, and land capability classes scaled from high to low capability on columns (see Tables 1 and 2). The number of rows and columns used will depend on the level of details desired and the availability of data on both population and land capability classes for small spatial units of analysis.

The basic data matrices for Zimbabwe result in two sets (communal and commercial) of arrays compiled from data on population density and land acreage potential using the smallest administrative units for which data are available. Tables 1 and 2 respectively are compilations of population numbers by density classes and land capability categories. Tables 3 and 4 are the respective communal and commercial acreage holding arrayed on the bivariate matrix.

In the case of Zimbabwe, the spatial data units are composed of 55 communal districts and 56 commercial districts, 111 data units altogether. Population and land area data are drawn from the Central Statistical Office (CSO) tabulations by census enumeration areas (CSO 1990).

Classification of land area of the 111 data units into the five categories of land potential are compiled by the author from overlays of two maps for Administrative Areas, and Natural Regions and Farming Areas (Surveyor General 1984, 1988). Zimbabwe is divided into five land capability classes based on moisture availability (Surveyor General 1984; Whitsun Foundation 1980:22-23) (Figure 1). These are commonly called natural regions and are designated by Roman numerals I to V. Natural regions I and II contain lands of high potential with moisture exceeding 750 mm. per annum and classified as suitable for 'intensive farming' (Surveyor General 1984). Lands in natural region III, which receive moisture ranging between 650 and 750 mm. per annum, are rated of marginal potential suitable for 'semi-intensive farming'. Natural regions IV and V, with annual moisture budget of less than 650 mm., are classified as low potential that can only support 'extensive farming' in combination with livestock (Surveyor General 1984; Nyamapfene 1990:22-29, Whitlow 1988b:24-28). For application to other African countries, data constraints may be experienced from lack of reliable data for small areas for either population density or land capability.

Evaluating Overall Spatial Mismatch

There are varying degrees of spatial mismatch that contribute to regional inequalities in opportunity for food security, sustainability of land-based enterprises and overall development. Although many SSA nations experience some degree of spatial mismatch, measures to differentiate orders of magnitude in terms of what we refer to as acreage and soil endowment equities have not been analysed in a systematic fashion.

Acreage equity refers to land proportional shares in crude acreage by user category (e.g. communal or commercial) commensurate with proportional shares in population by the respective user category. Similarly, soil endowment equity refers to ownership from all grades of land by user category in direct proportion to shares in population. The first outcome of analysis of spatial mismatch will therefore show the degree of equity in land distribution among the principal users of land in a given country. If data on land degradation are available for corresponding small areas, a second research objective in spatial mismatch analysis would be to investigate if acreage and soil endowment inequities have led to differential population pressure on arable land thereby adversely affecting sustainability of land resources.

In the case of Zimbabwe, acreage inequity has been a principal problem in rural development. Zimbabwe's small-holder communal population, which comprised of 73.3 percent of all rural population in the country, subsisted on just about half of the rural land surface (Tables 1 to 4; CSO 1990; CSO 1989). This has caused for over 60 percent of the communal rural population to live in 'high-density' settlements with a density of 30 people or higher per square kilometre, whereas only 17 percent of the commercial land population experienced this level of density. On the other hand, almost 60 percent of the commercial land population was located in 'low-density' areas of 14 people per square kilometre or less, while only a mere 10.4 percent of the communal small-holder population experienced such density. It can also be observed that nearly 44 percent of the communal population resided in densities exceeding 40 people per square kilometre whereas only less than 4 percent of commercial settlements reached this level of stress.

Patterns of soil endowment inequity are also evident in Zimbabwe's case study. According to Tables 1 and 2, the majority of the communal population, over 60 percent, resided in the least favoured regions of IV and V (see also Figure 1). Only about 15 percent of the communal land population lived in the more favoured regions of I and II. On the contrary, about 60 percent of the commercial land population resides in the most favoured regions of I and II. Tables 3 and 4 offer the details. Table 3 shows that over 70 percent of the communal small-holder land is in least-endowed regions of IV and V. Only about 10 percent of the communal land is in regions of I and II. The commercial domain, on the other hand, dominates best-endowed regions I and II occupying over 90 percent of the total land in region I and about 74 percent of total land in region II (Tables 3 and 4). Zimbabwe offers perhaps one of the best examples of spatial mismatch with very high levels of both acreage and soil endowment inequities in Africa (Mascarenhas 1983; Moyo 1986).

Quantitative Indicators of Spatial Mismatch

In order to gauge acreage and soil endowment inequities, a procedure that would compare the difference between expected equitable distributions of land, using population as base magnitude, and actual distributions of land is devised. The procedure uses a standardised descriptive non-parametric statistic which takes into account the bivariate nature of spatial mismatch data matrix demonstrative of land holding by competing sectors as in Zimbabwe's communal and commercial domains. The statistic, which is termed as land share quotient (LSQ), is a modified version of the location quotient (commonly used by geographers) and applied for the bivariate schedules of population density and land potential (Barber 1988:87-88; Haggett et al. 1977:301).

LSQ for a given user type of population (communal, commercial or other) is the quotient resulting from dividing the actual matrix cell proportional share of user category of total national land by the respective matrix cell value of proportional share of the total national population. Theoretical limits for LSQ cell values range between a minimum of 0 (when a given user category owns no land in that cell) to a maximum which is equal to the reciprocal of the respective actual population ratio. Actual rural population ratios for Zimbabwe's communal and commercial lands are 0.73 and 0.27 respectively. The respective reciprocals would therefore be 1.36 for communal and 3.74 for commercial domains.

LSQ which is equal or close to one in both communal and commercial table cells mean that rural land shares between the two user categories are equitable in those cells. Cell values less than one in either of the domains signify less than fair share, and values more than unity signify ownership exceeding the fair share in that specific category of land. Since acreage share is a zero-sum game, a higher-than-one LSQ cell value for one user category means lower-than-unity LSQ cell value for the other category. The cell values for each category of user represent the number of times of their expected equity share acreage of land that either communal or commercial domains have in a cell of a given population-density/land-capability table. In cells where LSQ maxima or close to maxima are shown for one category of user, the corresponding cells for the other user category have a value of zero or close to zero (see the Methodological Appendix for details).

LSQ values in Tables 5 and 6 illustrate quantitative magnitudes of acreage and soil inequities in Zimbabwe. Acreage inequity is illustrated by the presence of near maximum LSQ values for minority user category (commercial) which enjoys almost total monopoly of acreage in almost 20 of the 47 data cells (containing near 50 percent of the total national acreage) (see Table 6). Soil inequity is evidenced by the fact that in communal settlements, land ownership is severely skewed away from the upper-left sector of the table with maximum or close to maximum LSQ values concentrated in the less favoured lower-right sector which represents lands with high population densities and low land potential (Table 5). The exact opposite is true with respect to commercial users whose pattern of land ownership is highly skewed away from the lower-right sector of the table with virtual monopoly appropriation of the most favoured upper-left sector of the table (Table 6).

The high degree of spatial mismatch is exemplified by the fact that communal and commercial domains are clearly split along the diagonal of the bivariate table into almost totally mutually exclusive domains in which the commercial sector dominates the upper-left (high potential) sector of the table mirror-imaged by the communal sector in the lower-right (low potential) sector of the table (see Tables 5 and 6). The procedure may be replicated in any African country where competition for arable land between small-holder farming and large-scale commercial agriculture continues to pose problems for food security and rural development.

Spatial Mismatch and Land Degradation

In most SSA countries, land resources are fragile and, given the low level technology applied in the small-holder sector, carrying capacities can be very limited. Population pressure caused by spatial mismatch could have devastating consequences on rural food security. Conditions in the Sahel, the Horn and Eastern Africa have demonstrated this problem over the last two decades. Careful monitoring of land resources experiencing high levels of spatial mismatch is of particular significance as it will help prevent irreversible damages to land endowments in highly stressed lands. The case of Zimbabwe illustrates what could happen when high spatial mismatch is accompanied by the absence of policy to monitor and safeguard sustainability of land endowments.

In Zimbabwe, a colonial legacy of inequitable land distribution that favoured the commercial large-scale farming sector, has resulted in a high level of spatial mismatch as shown above. High rural densities on lands that are often extremely fragile produced deleterious effects on land endowments. A look at erosion research in Zimbabwe (Elwell 1985; Stocking and Elwell 1973; Whitlow 1988a:25; Marchand 1989; Kay 1975; Nyamaphene 1982) has amply demonstrated this problem for Zimbabwe. Table 7 is a compilation of archival data on erosion in small-holder communal lands. It shows that there is a clear pattern of spatial covariance between density in small-holder operators and land degradation (Table 7).

Communal settlements with high population densities (function of acreage inequity) and/or low land potentials (function of soil endowment inequity) are associated with higher magnitudes of erosion and degradation. About a third of the communal area, which is virtually all in the less favoured sector of the bivariate table, is 'affected by erosion' on over 12 percent of the land (Whitlow 1988a:25). This includes communal lands with low to medium population densities but located in less endowed regions IV and V (figure 1) (e.g. Gwanda, UMP Zvatadia, Mudzi and Pfura), communal lands with high population densities but located in better endowed regions II and III (e.g. Maungwe, Kubatana Bindura, Chirau, Zwimba, Chiweshe and Goromonzi Kubatana), and communal lands with both high population density and low land potential in regions IV and V (e.g. Bikita Peoples, Zaka, Mutare, Nyaningwe, Batanai and Buhera) (see CSO 1989:2). Research on deforestation (Whitsun Foundation 1981; Whitlow 1988b) and overgrazing (Mhlanga 1982) indicates almost similar patterns of distribution, most critical cases being located in the less favoured sector of the bivariate table (Table 7).

Policy Implications of Spatial Mismatch

Although the historical specifics of spatial mismatch may vary between regions, the same general processes have been evident in most SSA countries in which private or corporate plantation agriculture became important sectors in colonial as well as postcolonial economies. Invariably, low-density large scale plantations have expanded on high potential lands often at the expense of small-holder users (Williams 1981). There is at present an intense competition for scarce high potential land between these two domains. On the one hand, there is a pressure to expand high potential acreage under communal agriculture (Rukuni 1990:55; Goz 1981). This cannot be done without reducing commercial lands which produce important commercial crops for both local consumption as well as for export.

There are also concerns that expanding communal modes of production to land currently 'protected' under commercial or national reserves would be tantamount to introducing bad resource management habits into these 'protected' zones. The policy challenge for most SSA governments rests on designing a national land management system that contains multiple dimensions for improving conditions for small-holder populations without jeopardising the productive potentials of all lands and the overall sustainability of the national land resource base (Mhlanga 1982; Goz 1987).

Current land stresses and food insecurity, even famine, in some SSA small-holder localities may resemble Malthusian pressures with little prospect for successful transition to Boserupian technologies for intensification (Boserup 1981:200-211; Lipton 1990; Pingali 1990; Lele and Stone 1989). This may be the case for few locations in SSA. In most instances, land contraints are artificial and are results of faulty colonial or postcolonial policies that have resulted in densification of the small-holder sector while making vast amounts of high-potential land to commercial agriculture (Arrighi 1970; Weiner et al. 1985:254-256; see also Pingali 1990:256). Such exogenous intrusions in the rural economy of SSA have also disrupted traditional responses for sustainable use of land resources (Boserup 1981:8-28). Instead, the small-holder sector, faced by land stress not of its own creation resorted to 'soil mining' to eke out subsistence (see Lipton 1990:224; Reynolds 1982).

From the viewpoint of economic geography or environmental economics, what may be required is a comprehensive analytic design for land use policy that will redress spatial mismatch and enable institutional strategies for economic and technological integration of small-holder food and large-holder commercial sectors (Siebert 1985; Okigbo 1990; Chavunduka 1982, Goz 1982, 1983). This space will not allow an elaboration of such an approach. We shall simply outline four principal components of an integrated plan of action which, depending on the empirical circumstances in individual countries, can be applied in appropriate magnitudes to redress the negative externalities of current spatial mismatch structures.

The first option is increasing acreage for small-holder sector with options for voluntary resettlement of rural households currently operating at carrying capacities detrimental to both life and resources. This is perhaps the most difficult option to implement as it not only requires land reapportionment between small-holder and large scale enterprises, which can be a delicate political issue, but also calls for considerable financial outlays for planning and implementation. The second option is to target programs for conservation, reclamation, and sustained yields on communal lands. This is one of the more attractive options but implementation costs in both time and money can be quite demanding and it may not yield significant results for cases where the damage on land has been too serious. The third option is to infuse appropriate technologies including extension inputs and social infrastructure. This is among the most viable options. However, just as in the case of option two, the major constraint is cost. There is also the problem of the availability of appropriate technology for diffusion. The fourth and last option is increasing non-farm secondary and tertiary small enterprises along with appropriate levels of urban development. This is a very attractive option which is rarely given appropriate emphasis in rural development plans in SSA (Liedholm and Mead 1986). Urban-based development options using small-scale enterprises whose products can be sold locally or exported should be given serious attention. This option will stimulate urban dynamics in Zimbabwe's city-poor small-holder communal lands and enable them to retain potential outmigrants to overpopulated major cities.

Conclusions

In many SSA countries, land-based spatial mismatch has negatively impacted rural development, with particular reference to family food security, by moving high potential lands from food crops to non-food plantation schemes. In the process, small-holder farmers are relegated to more marginal lands whose carrying capacities are much lower than the population numbers they are expected to sustain. The results are not only food insecurity but also the degradation of land resources.

The case of Zimbabwe was used to demonstrate land use analysis to detect spatial mismatch in SSA's rural economy. Some conclusions are discernible. First, current land use pressure in small-holder food sector is detrimental to sustainable food security and overall development of the rural sector. Second, acreage and soil endowment inequities and associated environmental problems created by spatial mismatch in small-holder sectors are results of bad land distribution policy in colonial and postcolonial periods. Third, solutions to redress spatial mismatch and relieve land use pressure in the small-holder sector must be found in a comprehensive and integrated strategy that is not limited to the search for 'new lands' suitable for small-holder agriculture but also include improved stewardship of existing land resources, diffusion of production technology and social infrastructure, and advancement of urban sector options. In most cases, spatial mismatch is an artefact of land management under 'bimodal' or 'dualised' modes of production (Johnston 1986) in which the small-holder sector was marginalised. It is not a natural outcome of spontaneous and endogenous processes that resulted from choices and markets. It will require deliberate actions for redress based on policy research that includes both rural and urban options.

Methodological Appendix

For the case of Zimbabwe, LSQ computation demonstrated using the 5 by 11 matrices for population and land provided in Tables 1 to 4. The derived LSQ matrices for communal and commercial land respectively are shown on Tables 5 and 6. LSQ cell value are computed for each cell containing acreage data. LSQ tables are prepared for communal and commercial domains separately using their respective population and land area data. LSQ cell values are computed in two steps. First, a contingency table (not included here) of expected equity-acreage shares is derived for communal land (eCNA) and for commercial land (eCCA) using their respective population shares as equity proportional magnitudes (see Equations 1 and 2).

$$ {}_{e}CNA_{ij} = ({}_{a}CNA_{ij} + {}_{a}CCA_{ij}) \times \frac{{}_{a}CNP}{({}_{a}CNP + {}_{a}CCP)} \quad \text{(Eq. 1)} $$

$$ {}_{e}CCA_{ij} = ({}_{a}CNA_{ij} + {}_{a}CCA_{ij}) \times \frac{{}_{a}CCP}{({}_{a}CNP + {}_{a}CCP)} \quad \text{(Eq. 2)} $$

Where:

CNA_{ij} = Communal land acreage in cell of density i and NR j.
CCA_{ij} = Commercial land acreage in cell of density i and NR j.
CNP = Total population residing in communal lands.
CCP = Total population residing in commercial lands.
i = Density classes (1 to m = 11).
j = Land capability classes (1 to n = 5).
a = Actual values of acreage and population.
e = Expected equity values of acreage.
NR = Natural region (land capability class).

Second, the actual cell values of acreage for communal areas (${}_{a}CNA$) shown in Tables 3 and those for commercial areas (${}_{a}CCA$) shown on Table 4 are then divided by the respective corresponding expected cell acreage values for the communal (${}_{e}CNA$) and commercial (${}_{e}CCA$) areas. The step produces the LSQ matrices for communal and commercial domains respectively as shown on Tables 5 and 6 (Equation 3 and 4).

$$ LSQ(CNA)_{ij} = \frac{{}_{a}CNA_{ij}}{{}_{e}CNA_{ij}} \quad \text{(Eq. 3)} $$

$$ LSQ(CCA)_{ij} = \frac{{}_{a}CCA_{ij}}{{}_{e}CCA_{ij}} \quad \text{(Eq. 4)} $$

Where:
LSQ_{ij} = Land share quotient for cell of density i and NR j. Other symbols as defined for Equations 1 and 2.

There are as many LSQs as there are data cells in any of the bivariate Tables 1 to 4. There are also as many LSQ tables as there are user categories. In the case of Zimbabwe, for example, two LSQ arrays were generated, one for communal (Table 5) and one for commercial (Table 6) sectors.

Table 1: Small-holder Land Population by Density and Natural Regions (in thousands)

Population Density p/sq. km	Natural Regions I	II	III	IV	V	Total	Percent of Total
0 - 4	0.0	0.0	0.0	3.0	7.0	10.0	0.2
5 - 9	0.0	2.8	6.1	24.0	81.8	114.7	2.7
10-14	0.0	14.1	19.6	192.4	94.0	320.1	7.5
15-19	0.0	19.2	139.8	254.8	119.3	533.1	12.5
20-24	0.0	52.4	63.7	201.0	67.3	384.4	9.0
25-29	0.0	35.6	56.7	203.4	0.0	295.7	6.9
30-34	0.0	67.6	126.8	155.4	67.4	417.2	9.8
35-39	0.0	0.0	0.0	207.4	132.0	339.4	7.9
40-44	0.0	14.0	155.2	391.7	180.7	741.6	17.4
45-49	14.9	118.6	233.7	21.1	22.2	410.5	9.6
50 & +	36.8	301.2	138.1	203.0	27.0	706.1	16.5
Total	51.7	625.5	939.7	1857.2	798.7	4272.8	100.0
Percent	1.2	14.6	22.0	43.5	18.7	100.0	

Source: Population density classes compiled from CSO (1990).
Map overlays and area estimates based on Administrative and Natural Regions 1:1 million scale maps (Surveyor General 1988, 1984).

Table 2: Commercial Land Population by Density and Natural Regions (in thousands)

Population Density p/sq. km	Natural Regions I	II	III	IV	V	Total	Percent of Total
0 - 4	0.0	0.0	32.5	70.9	38.5	141.9	9.1
5 - 9	16.7	42.0	134.6	69.7	0.0	263.0	16.9
10-14	19.9	232.7	66.4	91.7	105.7	516.4	33.2
15-19	0.0	121.2	18.0	7.0	0.0	146.2	9.4
20-24	14.8	81.4	9.9	4.9	0.0	111.0	7.1
25-29	65.9	49.5	0.0	0.0	0.0	115.4	7.4
30-34	54.7	156.4	0.0	0.0	0.0	211.1	13.6
35-39	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-44	0.0	52.4	0.0	0.0	0.0	52.4	3.4
45-49	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50 & +	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	172.0	735.6	261.4	244.2	144.2	1557.4	100.0
Percent	11.0	47.2	16.8	15.7	9.3	100.0	

Source: Population density classes compiled from CSO (1990).
Map overlays and area estimates based on Administrative and Natural Regions 1:1 million scale maps (Surveyor General 1988, 1984).

Table 3: Communal Land Acreage by Population Density and Natural Regions (Area in thousands of hectares)

Population Density p/sq. km	Natural Regions I	II	III	IV	V	Total	Percent of Total
0 - 4	0.0	0.0	0.0	108.9	254.2	363.1	2.1
5 - 9	0.0	55.5	105.4	427.3	1144.0	1732.2	10.2
10-14	0.0	111.4	171.0	1668.8	877.2	2828.4	16.6
15-19	0.0	98.5	821.7	1523.8	731.2	3175.2	18.6
20-24	0.0	242.6	295.8	950.5	316.3	1805.2	10.6
25-29	0.0	126.2	200.8	756.0	0.0	1083.0	6.4
30-34	0.0	203.0	391.0	474.5	214.6	1283.1	7.5
35-39	0.0	0.0	0.0	553.5	356.9	910.4	5.3
40-44	0.0	32.9	372.4	925.0	422.0	1752.3	10.3
45-49	30.2	244.8	487.9	45.3	48.4	856.6	5.0
50 & +	60.5	481.4	265.7	395.9	52.6	1256.1	7.4
Total	90.7	1596.3	3111.7	7829.5	4417.4	17045.6	100.0
Percent	0.5	9.4	18.3	45.9	25.9	100.0	

Source: Population density classes and figures are compiled from CSO (1990). Acreage in Natural Regions compiled using CSO (1990) and Surveyor General (1984, 1988).

Table 4: Commercial Land Acreage by Population Density and Natural Regions (Area in thousands of hectares)

Population Density p/sq. km	Natural Regions I	II	III	IV	V	Total	Percent of Total
0 - 4	0.0	0.0	1103.1	2636.3	2421.3	6160.7	36.7
5 - 9	199.3	482.2	1966.4	1041.8	0.0	3689.7	22.0
10-14	157.1	1914.9	559.7	863.1	872.7	4367.5	26.0
15-19	0.0	707.5	117.5	45.8	0.0	870.8	5.2
20-24	65.0	339.8	43.3	21.7	0.0	469.8	2.8
25-29	239.6	177.1	0.0	0.0	0.0	416.7	2.5
30-34	184.6	492.	0.0	0.0	0.0	676.6	4.0
35-39	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-44	0.0	118.6	0.0	0.0	0.0	118.6	0.7
45-49	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50 & +	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	845.6	4232.1	3790.0	4608.7	3294.0	16770.4	100.0
Percent	5.0	25.2	22.6	27.5	19.6	100.0	

Source: Population density classes and figures are compiled from CSO (1990). Acreage in Natural Regions compiled using CSO (1990) and Surveyor General (1984, 1988).

Table 5: Communal Land Share Quotients (LSQ)

Population Density p/sq. km	Natural Regions I	II	III	IV	V
0 - 4	–	–	0	0.1	0.1
5 - 9	0	0.1	0.1	0.4	1.4
10-14	0	0.1	0.3	0.9	0.7
15-19	–	0.2	1.2	1.3	1.4
20-24	0	0.6	1.2	1.3	1.4
25-29	0	0.6	1.4	1.4	–
30-34	0	0.4	1.4	1.4	1.4
35-39	–	–	–	1.4	1.4
40-44	–	0.3	1.4	1.4	1.4
45-49	1.4	1.4	1.4	1.4	1.4
50 & +	1.4	1.4	1.4	1.4	1.4

Source: Compiled by author.
Note: – = Cells in which no acreage is present.
LSQ figures rounded to one decimal.

Table 6: Commercial Land Share Quotients (LSQ)

Population Density p/sq. km	Natural Regions I	II	III	IV	V
0 - 4	–	–	3.7	3.6	3.4
5 - 9	3.7	3.4	3.6	2.7	0.0
10-14	3.7	3.5	2.9	1.3	1.9
15-19	–	3.3	0.5	0.1	0.0
20-24	3.7	2.2	0.5	0.1	0.0
25-29	3.7	2.2	0.0	0.0	–
30-34	3.7	2.7	0.0	0.0	0.0
35-39	–	–	–	0.0	0.0
40-44	–	2.9	0.0	0.0	0.0
45-49	0.0	0.0	0.0	0.0	0.0
50 & +	0.0	0.0	0.0	0.0	0.0

Source: Compiled by author.
Note: – = Cells in which no acreage is present.
LSQ figures rounded to one decimal.

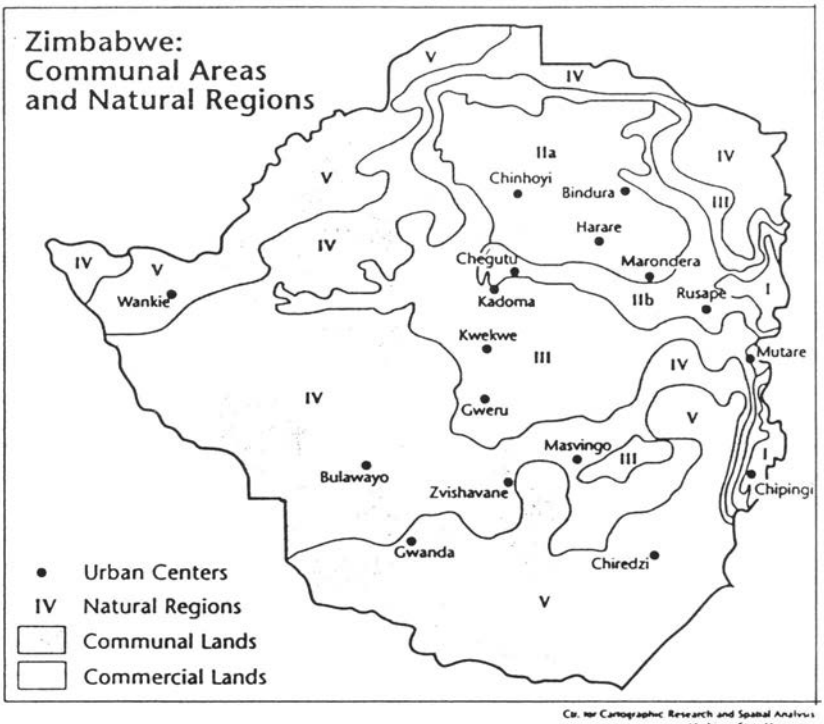
Table 7: Percent of Small-holder Communal Land in Cell Classified as under 'Desperate Pressure', 'Extreme Pressure', and 'Great Pressure' by Kay (1975)

Density	Natural Regions				
	I	II	III	IV	V
0 - 4	–	–	–	0.0	0.0
5 - 9	–	0.0	0.0	0.0	0.0
10-14	–	0.0	0.0	0.0	0.0
15-19	–	0.0	0.0	10.5	51.2
20-24	–	49.1	26.8	0.0	0.0
25-29	–	0.0	0.0	21.9	–
30-34	–	0.0	57.2	64.7	100.0
35-39	–	–	–	100.0	100.0
40-44	–	100.0	100.0	100.0	100.0
45-49	100.0	100.0	100.0	100.0	100.0
50 & +	0.0	75.0	94.3	100.0	100.0

Source: Compiled by author.

Note: – = Cells which zero acreage for communal lands. Land pressure area estimates compiled from map by Kay (Whitsun Foundation 1980, pp.21-23).

Figure 1: Spatial Mismatch between Small-holder Areas and High Potential Land



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