Achieving Household Food Security: How Much Land is Required?

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1. Introduction

Global hunger is on the rise (FAO, 2009). The number of those that are undernourished has increased steadily over the past decade reaching 1.02 billion people in 2009 (FAO, 2009), and remaining near this total over the past two years. The Millennium Development Goal to reduce world hunger by half by 2015 will likely not be met with current observed trends according to a recent UN report on food insecurity and world hunger (FAO, 2009). Limited land and growing population (Gerbens-Leenes and Nonhebel, 2005), global yield decline (Alston *et al.*, 2009), financial resources and the economic downturn in 2008 are a few reasons that have led to the recent trend in world hunger.

As of 2010, some 237 million or 21% of the total population in India remain undernourished (FAO, 2011). While the percentage decline is an improvement over the 25% in 1990; a large portion of the population still does not consume even the minimum recommended daily intake of energy and protein. Further, a 2001 survey of the diet and nutritional status of India's rural populations indicated that across all age and physiological groups, the consumption of most foods was below the recommended daily intake as set out by the Government of India (NNMB, 2002). The problem was underlined in a recent report of the International Food Policy Research Institute, which recognizes that some 40% of India's children are malnourished, with mortality rates of 2.5 million per year attributed to inadequate food consumption (von Braun *et al.*, 2008). This represents one out of every five such deaths in the world; the rate of malnutrition is double that of Sub-Saharan Africa and five times that of China (von Braun *et al.*, 2008). Several reports indicate that there is an urgent need for a comprehensive nutrition strategy including incentive-oriented policies that involve community and household participation in order to ensure adequate production and retention of food within communities (McIntyre *et al.*, 2001; von Braun *et al.*, 2008). For rural regions of India, this is particularly true as villages are often far removed from other sources of income and from the larger agricultural markets in urban centres.

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As India's population continues to increase, the pressure on land resources to supply the food and fodder demands of households will be ever greater, calling for a need to utilize on-farm resources more efficiently. While yield is a key aspect to improved nutrition (FAO, 2009), optimal allocation of crops and livestock within a given land area is also an important factor towards food security.

The present study seeks to develop methodology that can be employed to determine how much land is required to satisfy the basic human nutritional requirements of a household, and in other instances livestock requirements in terms of fodder demand. Primary data on land and population inventories are used to compare the minimum land area requirements among the various different landholding and crop yield categories. The aim of the present study is to inform policy on the essential land requirements necessary to meet the nutritional demands of households.

2. Methodology

The micro-level household survey of mixed cropping / livestock systems and associated land use was carried out in the semi-arid region of northern Karnataka state, in southern India, during October and November in 2007 (Figure 1). In this part of the state, two crops

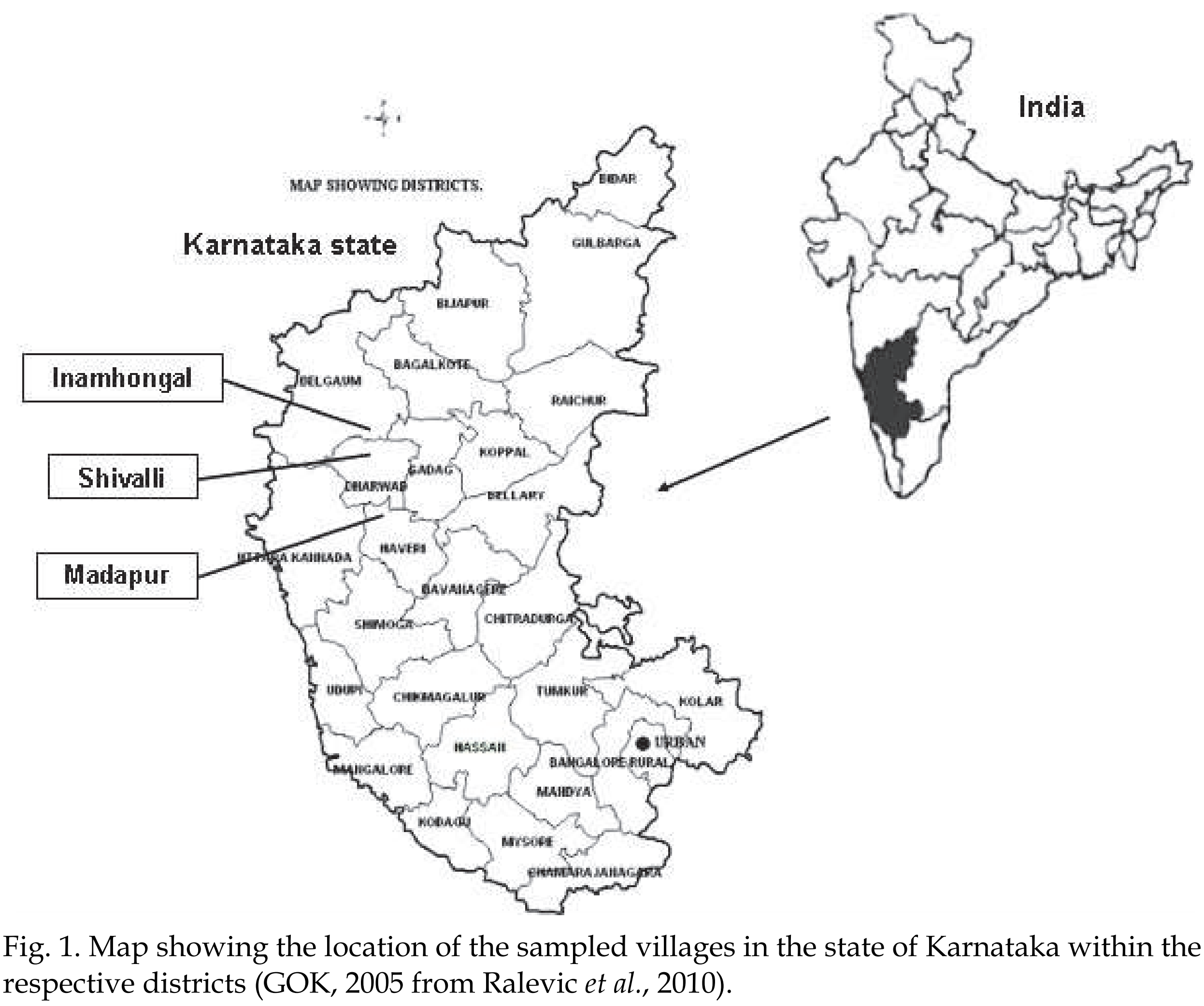

Fig. 1. Map showing the location of the sampled villages in the state of Karnataka within the respective districts (GOK, 2005 from Ralevic *et al.*, 2010).

can be grown, depending on availability of water: the *kharif* crop cultivated during and after the monsoon season and the *rabi* crop during the drier winter months. Three villages were sampled: Inamhongal (N 15° 37.623′, E 75° 04.551′, Zone-III) Belgaum district, Madapur (N 15° 03.250′, E 75° 18.095′, Zone-VIII) Haveri district and Shivalli (N 15° 28.135′, E 075′08.435′, Zone-VIII) Dharwad district (Figure 1). Data were gathered in order to determine the base year crop distribution, production and needs for food and fodder of individual households within various landholding categories: landless, marginal (0-1 hectares), small (1.01-2 ha), medium (2.01-4 ha) and large (>4.01 ha). These base year data describe the situation for the *kharif* crop harvested in late 2006 and the *rabi* crop harvested in 2007. A detailed account of the region, survey methodology, primary data collection procedures, and social indicators can be found in Ralevic *et al.* (2010).

In the present study, the definition of household size or population is based on consumptive units (CU) as set out in Table 1, and from this the nutritional demands were calculated (Ralevic *et al.*, 2010). All livestock-related calculations are similarly done on a livestock unit (LSU) basis, where 1 livestock unit represents an equivalent of 1 bullock, buffalo or lactating dairy cow. The LSU equivalents are used to determine the fodder demands which for 1 LSU (lactating dairy cattle) is assumed to be 2.17 t dry / y .

Group	Consumptive unit
Adult male (moderate work)	1.2
Adult female (mod. w.)	0.9
Adolescents (12-21 yrs)	1
Children (9 to 12 yrs)	0.8
Children (7 to 9 yrs)	0.7
Children (5 to 7 yrs)	0.6
Children (3 to 5 yrs)	0.5
Children (1 to 3 yrs)	0.4

Table 1. Human nutritional consumptive units (adopted from Gopalan *et al.*, 1996).

Using the collected demographic data, the average household nutritional needs within the landholding categories were determined. A linear optimization model was then used to run various land area requirement scenarios using a variety of constraints and objectives as in Ralevic *et al.* (2010). The linear model was constructed in excel using the What'sBest LINDO software ad-ins for optimization. The objective function in all scenarios modeled was to minimize land area. In the present paper, the following scenarios are evaluated:

1. The minimum land area required to satisfy basic human food energy and protein needs of individual households under presently observed yields and three cropping intensities; 200% (upper) , 164% (present average situation) and 150% (lower).

Objective function:

Minimum land area = Land area in the *kharif*[1], *and* where

[1] Field data has shown that nearly all land is cultivated in the *kharif* season. Therefore, the minimum land area is based primarily on the cultivation within the *kharif* season, with anything over a 100% intensity being cultivated in the *rabi* season.

Land area in *rabi* = Land area in the *kharif* x (Cropping Intensity ratio -1)

$$MinLA = \sum_{cv} L_{cv,s1} \text{ , where } \sum_{cv} L_{cv,s2} = \sum_{cv} L_{cv,s1} x(CI_R - 1) \quad (1)$$

where LA = Land Area, cv = 1,2,3…14, $s1$ = *kharif*, $s2$ = *rabi*, R = 1, 2,3.

Cropping intensity ratio= (land area used in the *kharif* season + land area used in the *rabi* season) / total available land area (also expressed in percent).

2. The minimum land area required to satisfy the fodder demands in addition to food requirements under current yields and under three cropping intensities of 200% (upper), 164% (present situation) and 150% (lower).

Fodder demands were determined based on the number of livestock units per household.

The food energy and protein demand constraints, as well as the fodder demand constraints and the input data are outlined in Ralevic *et al.* (2010).

3. The findings

3.1 Households and land in the study area

For the three villages, the base year data on average household size and average land area are presented in Table 2. The average household population in the villages ranged from 5 to 6.5 CUs with a weighted average of 5.8 consumptive units. The CU value differed depending on the size of landholding, with larger landholders tending to support larger families compared with those who had little or no land. Average holding of land by households within the four categories ranged from 0 ha/hh (landless households) to 8.2 ha/hh (large households). More detailed demographic information can be obtained from Ralevic *et al*., (2010).

Land category	Land area (ha/hh)	Population (CU/hh)	Livestock units (LSU/hh)	Sample-wide landholdings (% of total)
Landless	0	5	0.09	17
Marginal	0.63	5.3	0.53	21
Small	1.55	5.7	1.10	25
Medium	2.85	6.5	2.35	20
Large	8.16	6.5	4.08	16
Weighted total	2.38	5.80	1.63	~100

CU = consumptive unit, LSU = livestock unit, hh = household

Table 2. Population and land area data for sampled households presented as a weighted average among landholding categories.

3.2 Mix of crops and cropping intensity in the base year

The study area is in a region of the country that supports a considerable diversity of crops grown during the two agricultural seasons. Variations both in precipitation and in soil types among the villages influence cropping patterns and intensity of cropping (UAS, 1985). Table 3 shows the cropping intensity and the crop types that were cultivated in the three villages during the base year. Depending on the village, about three quarters of the land was planted to a variety of pulses, oilseeds and commercial crops, while the remaining one quarter was devoted to cereals in all three cases.

	Village		
	Inamhongal	Madapur	Shivalli
Total cultivable land area (ha)	1805	704	1117
Cropping intensity (%)	182	118	192
Cereals (%)	25.8	23.4	23.4
Pulses (%)	53.8	1.1	26.6
Oilseeds (%)	1.4	23.3	24.6
Commercial crops (%)	18.9	40.4	25.2
Other[1]		11.8	

[1] Includes non-principal crops reported by a small number of households (i.e. coconut, banana etc.).

Table 3. Percent of total cultivable land devoted to crops during the base year among the sampled villages for the *kharif* and *rabi* seasons.

The intensity of cropping was highest in Shivalli, at 192%, followed by Inamhongal at 182% and Madapur at 118%.

In Inamhongal, the principal crops in the *kharif* season were maize, horsegram, greengram and onion, and in the *rabi* season, sorghum, wheat, maize and bengalgram. Cotton was also cultivated throughout the *kharif* and *rabi* seasons. Unlike in the other two villages, chilli, a high value commercial crop commonly grown in this area, was not cultivated here, given that chilli is grown in red soils (UAS, 1985) and is therefore unsuitable for Inamhongal's black soils. Similar to chilli, nuts and oilseeds are predominantly absent due to nuts such as groundnut favouring growth in light red soils. Of the three villages, Inamhongal had the most diverse cropping pattern.

The principal crops cultivated in Madapur were mainly commercial in nature, including chilli, cotton, and groundnut. There was only limited production of foodgrains in Madapur and there was much less village-wide crop diversity as was observed in Inamhongal. The high value and assured market for the commercial crops heavily contributed to the observed pattern of cultivation. With regard to the low cropping intensity, the under-utilization of land was due to a combination of factors, including the inability of farmers to purchase the material inputs, such as high quality seed and fertilizer, necessary to cultivate the additional land (Singh *et al.*, 2007), as well as the limited availability of labour (Singh and Marsh, 1994; Suryanarayana, 1997). Discussions with farmers in Madapur pointed out that there was a shortage of labour and lack of irrigation that could have been accessed during periods of limited rainfall particularly in the *rabi* season.

In Shivalli, a diverse cropping pattern was observed that included crops from all four of the major crop groups: cereals, pulses and legumes, nuts and oilseeds and commercial crops. The principal crops cultivated during the *kharif* season were horsegram, greengram, groundnut, onion and chilli, and in the *rabi* season, sorghum, wheat, bengalgram and sunflower were grown.

In each of the villages, compared with other categories, grain crops were generally more productive in terms of amount of food energy generated per hectare. Crop yields (Table 4) of specific crops were similar within all three villages and are comparable to yields in other dryland parts of India during the same year.

Crop variety	Yield (t/ha)	
	Kharif	*Rabi*
Sorghum	1.28	0.81
Wheat		0.66
Maize	2.24	
Bajra	0.76	
Greengram	0.57	
Redgram	0.42	
Horsegram	0.77	
Bengalgram		0.76
Groundnut	1.14	
Sunflower	0.30	0.30
Safflower	0.25	0.40
Chilli	0.67	0.15
Onion	5.08	2.95
Cotton	0.73	0.73

[1] Primary data.

Table 4. Average crop yields for selected seasons of cultivation in 2006-2007 within the sampled villages (see Ralevic *et al.*, 2010). A blank cell indicates that the particular crop was not cultivated during the indicated season.

Given the central importance of providing for household food security, it is interesting to separately examine the types of crops grown by farmers who had only limited amounts of land, i.e. those having marginal and small landholdings (Table 5).

Crop category	Marginal (%)		Small (%)	
	kharif	*rabi*	*kharif*	*rabi*
Cereals	2.7	15.9	9.3	36.8
Pulses	35	18.5	36.2	22.6
Oilseeds	19.3	8.7	16.2	8.5
Commercial crops	28.6	20.5	34.0	9.7
Other crops	8.1	0	2.5	1.6
Fallow land	6	36	1	20
Total (%)	~100	~100	~100	~100
Average land area (ha)	0.63		1.55	

Table 5. Crop categories cultivated by farmers having marginal and small landholdings for the base year as a weighted average for all sampled villages.

For marginal households, commercial and other cash crops (pulses and oilseeds) made up about 88% and 75% of total cultivated land during the *kharif* and *rabi* seasons respectively while for small households, the same figures were 86% and 53% during the base year. This meant that, on average, only a small portion of the limited land area for these households was used to produce food grains, the basic component of their dietary requirements. This portion was considerably less than that of the medium and large landholders.

3.3 Current nutritional status of the population

Using the information regarding average household size and production data for farmers in the various landholding categories, it is possible to determine the extent to which fundamental energy and protein nutrient requirements were provided on farm for the average case. Such base year calculations show that a large portion of the population currently living within the villages was unable to achieve food security under cropping conditions during the year under investigation (Figure 2).

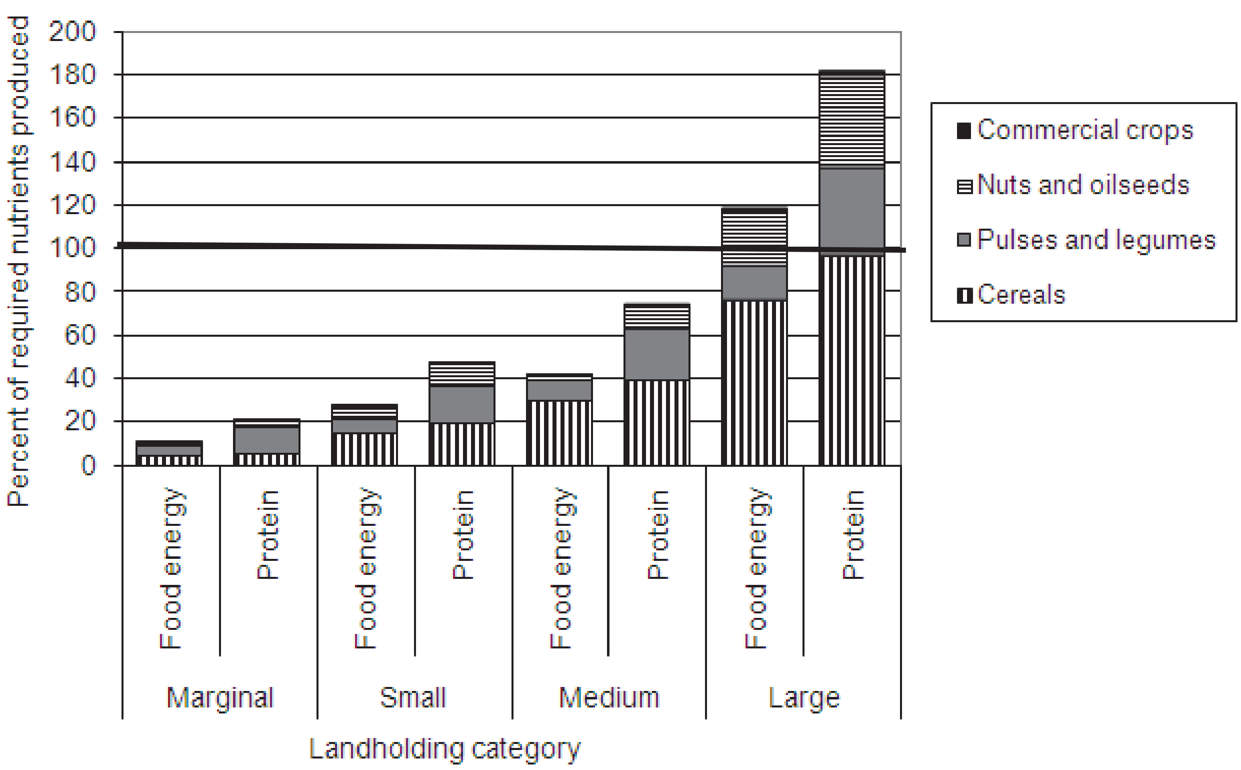

Fig. 2. Total calculated household food energy and protein produced within the landholding categories during the base year, in relation to the required nutrient level for a basic diet, as a percentage of total requirements (retrieved from Ralevic *et al.*, 2010). For each landholding type, a breakdown of nutrient production by crop category is presented.

According to these results and the population distribution within landholdings (Table 2), total household production made up 40 % of the villages' caloric requirement and 66% of the protein requirement excluding milk production. When milk production is included in the calculation, total household production made up 48% of the villages' calorific requirement and 79% of the protein requirement. The average values indicate that only the 14% of households having land holdings greater than 4 ha could produce sufficient food to satisfy nutritional demands. The remaining 86% could not achieve household food security through their individual agricultural activities, even under an assumption that all of the food that is produced is consumed within the village. These assertions are based on the assumption that the village average crop distribution was practiced in each case. Individual personal consumption of foodstuffs was not measured during the field survey, but the data indicate that the farmers with large landholdings sold surplus production of cereal-based crops to households within the village and to the wider market. This is also supported by work of Babu *et al.* (1993).

Therefore, on average, large landholding households would be able to consume an adequate amount of on-farm food energy and protein, while landless, marginal, small and even many medium landholdings must depend in large part on purchase of food to meet these requirements (Babu *et al.*, 1993). Field observations suggested that even when it was necessary to purchase food, persons in these lower income households generally appeared malnourished. Therefore, present land area constraints, low yields and high population demands all contribute to some level of undernutrition.

3.4 Minimum land area needed to provide for household food security

It is clear then, that in the base year using the average number of household members within the villages, most farmers would not be able to satisfy their household food requirements under the current cropping conditions. Improvements in yield and/or increased cropping intensity would be two obvious ways in which the food needs of the local populations could be more closely met. Our interest in this research, however, was to examine whether rational design of crop selection could also contribute to a larger and more appropriate supply of food. A question that we wished to address is "Can optimizing crop selection contribute to improved nutrition within this area?"

With this goal and using the objective of finding the minimum land area required to satisfy nutritional requirements as defined above, a new optimal cropping pattern was calculated for each village. Examples of the recommended crop distributions for a household having 5.8 consumptive units and 0 to 3 livestock units are given in Table 6. In the optimized model, cereals are given prominence especially in the highly productive *rabi* season, because of their high energy yield and nutritional status. Given their high fodder yield, they become especially important in cases where the household keeps cattle.

The table shows that, with a cropping intensity of 1.5, the minimum land area needed to provide for food security when crop distribution is optimized is just over 2 ha. This places the area requirement at the border between the small and medium landholding categories. In the study area, only 36% of the households had an area of land of 2 ha or more.

When the household has no livestock, the protein requirements are met by producing and consuming a good supply of pulses, mainly greengram and horsegram, during the *kharif* season. When the household had one milk-producing animal, there was less need to produce pulses as a protein source .The reduction in pulses could then be substituted by increased production of commercial crops. Therefore, with the same land area, having one cattle would be able to increase the net value of products. As the number of cattle is increased to two or three, the same minimum land area could provide for food security, but more of the land would need to be planted to cereal crops to cover for the fodder needs, thus reducing the commercial crops.

	Livestock units							
	0		*1*		*2*		*3*	
Crop category	*kharif*	*rabi*	*kharif*	*rabi*	*kharif*	*rabi*	*kharif*	*rabi*
Cereals	5.4%	96.7%	5.4%	96.7%	26.6%	96.7%	60.6%	96.7%
Pulses	55.2	3.3	49.6	3.3	43.6	3.3	37.6	3.3
Nuts and oilseeds	1.8	0	1.8	0	1.8	0	1.8	0
Commercial crops	37.5	0	43.4	0	28.3	0	0	0
Total (%)	~100	~100	~100	~100	~100	~100	~100	~100
Optimal land area (ha)	2.03	1.02	2.03	1.02	2.03	1.02	2.03	1.02
Net value of products (Rs)[2]	27,650		38,710		44,320		54,180	

[1] Consists of 2 adult males, 2 adult females, 1 adolescent, and 1 child who is 5-7 years of age.

[2] Includes the value of all crops, milk, manure and fuel that may have been produced from the cropping pattern and livestock combinations.

Table 6. Calculated optimal cropping pattern by crop category under a minimum land area scenario for achieving food security for the average household having a CU[1] of 5.80 and cropping intensity of 150%.

Using a similar optimization strategy, the minimum land requirements can be recalculated for situations where the cropping intensity is varied. Table 7 provides such values when the cropping intensity is 150%, 164% (the current average intensity in the three villages) and 200%. Once again, it is important to note that the estimates are based on employing current yield values in the calculation.

As shown in the table, when the need to provide fodder for livestock is taken into consideration together with the need to satisfy basic human requirements, the minimum land area generally may increase depending among other things, on cropping intensity and the number of livestock. Note that for 0 livestock the land area required in most cases is the same as if there were 1 or 2 livestock.

	Cropping intensity (%)	Livestock units (all cattle)			
		0	1	2	3
Minimum land area (ha)	200	1.02	1.02	1.18	1.51
	164	1.59	1.59	1.59	1.83
	150	2.03	2.03	2.03	2.03

Table 7. Minimum land area needed to provide for the nutritional needs of humans and cattle. Throughout the study area, the current average land use intensity is 164 %.
CI = cropping intensity, CU=consumptive units/household.

Figure 3 shows and extends the results under the three cropping intensity scenarios for situations where greater numbers of cattle are kept within the household.

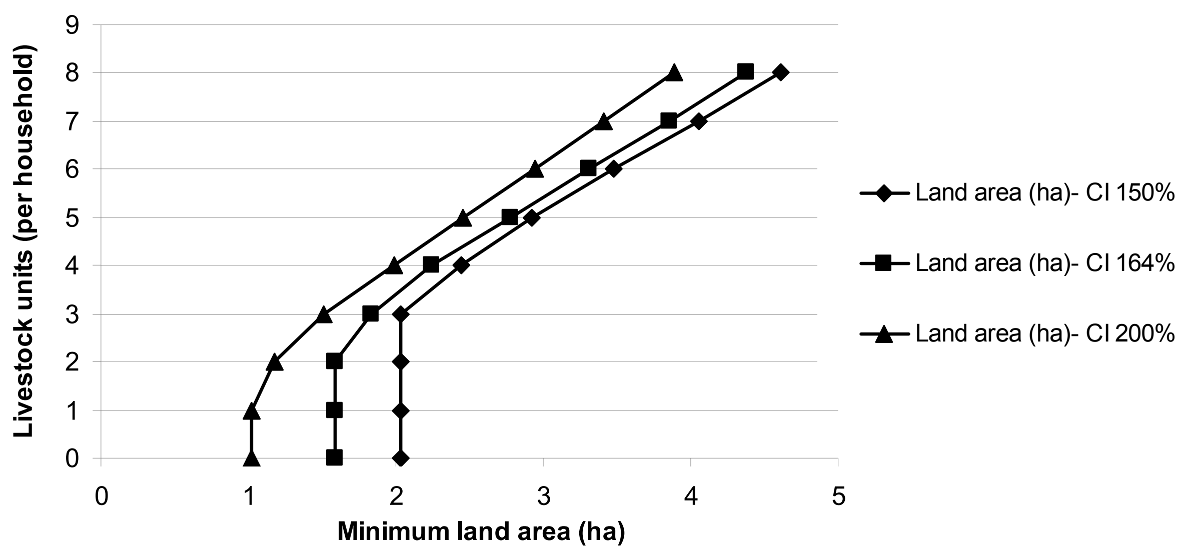

Fig. 3. Minimum land area based on livestock units as well as on average consumption units on a household basis for marginal, small, medium and large households.

The results shown in Figure 3 further illustrate the relation between human and animal nutritional requirements.Under all cropping intensities the minimum land area does not increase when there are a small number of livestock, since sufficient fodder is available in the form of the secondary biomass from the principal crops such as sorghum and maize. In the case of the 164% intensity, up to 2 livestock units can be supported on the same amount of land that is required to support only the household members. Above 2 LSUs, the demand for fodder drives the minimum land area requirement, similar to what Gerbens-Leenes and Nonhebel (2005, 2002) have found.

In the present situation, it was found that small and marginal households kept on average 1.1 and 0.53 livestock units respectively each, equivalent to each or every second household having one cattle or buffalo. From the field observations presented here, such households are unable to independently feed themselves and also are unable to produce the required fodder needed by the animal. Such households will be dependent on other larger farms for food as well as additional land for grazing .

In comparison, using optimal crop selection and the current 164% cropping intensity, small households having the average land area of 1.55 ha could potentially satisfy both the basic nutritional requirements within their households as well as the nutritional needs of up to 2 livestock units equivalents.

4. Minimum land area requirements: Comparisons with other studies

Other studies (Gerbens-Leenes *et al.*, 2002; Gerbens-Leenes and Nonhebel, 2005, 2002) have quantified the minimum land area that is required to satisfy food requirements of a given population. These studies calculate the amount of land needed to provide nutrients through 'singular foods', or single crops, as well as through several crops in line with the consumption patterns of the population. Although the studies deal with the Dutch population and, as recognized by the authors, cannot be applied as a direct comparison to India's population, they nonetheless highlight important relationships with respect to food and land area that are also evident in the present study. First, the studies found that a shift in diet to one containing animal foods or products requires more land. Gerbens-Leenes *et al.*, 2002 and Gerbens-Leenes and Nonhebel, 2005, 2002 also found that increases in land area are required to satisfy the fodder demands of the livestock, similar to the results of this study.

Second, when consumption patterns are included such that a variety of crops are grown, land area requirements increase. For instance, Gerbens-Leenes *et al.* (2002), and Gerbens-Leenes and Nonhebel (2005, 2002) found that when the consumption pattern was not considered, a singular high-yielding crop would be 'optimized' for production. In other words, when constraints[2] for the various crops to be consumed are removed, the required land area to maintain a minimum level of food energy and protein decreases. However, including a more diverse consumption pattern and requirements for agrobiodiversity leads to more realistic results and should also be considered in the optimization model. The diversity constraint was set in this study by fixing the consumption of certain crops under each food category such that: 45 % from the required cereal consumption would have to be made up by sorghum, 25 % by maize, 30 % by wheat. Under the required pulse consumption, 30 % would have to come from greengram, 30 % from bengalgram, and 40% from horsegram (see also Ralevic *et al.*, 2010).

The cropping pattern also illustrates that mixed cropping or more diverse cropping provides the necessary balanced diet for a household (Gerbens-Leenes *et al.*, 2002; Gerbens-Leenes and Nonhebel, 2005, 2002). In this study, the results should be taken to mean that a certain proportion of different food groups should be cultivated, but not necessarily the

[2] Constraints requiring certain proportion of cereals and certain proportion of pulses to be consumed by the household.

exact mix of species in land area as suggested. For instance, using data from Table 6, consider a household having two hectares of land and one cow that wishes to satisfy nutritional requirements and be self-sufficient, given the current yields. This household could cultivate mostly cereals in the *rabi* season, and a mixture made up substantially of pulses and commercial crops on the reduced amount of land cultivated during the *kharif* season. The specific choice of grains and legumes could depend on the farmers' preference.

To our knowledge no studies could be found that calculate the minimum land area for the Indian household production system in the dryland region applying optimization methodology. Previous optimization studies (Parikh and Ramanathan, 1999; Kanniappan and Ramachandran, 1998; Raja *et al.*, 1997; Painuly *et al.*, 1995; Singh and Marsh, 1994; Parikh, 1985; Parikh and Kromer, 1985) did not optimize for minimum land area.

Present day pattern of land distribution within the sampled villages has very important implications in achieving food security. Seventeen percent of the population is landless and therefore are highly vulnerable in terms of undernutrition. And there is great disparity in terms of landholdings amongst the peasant farmers. The average *per capita* land area for large landholdings at 1.41 ha is nearly 12 times larger than the 0.12 ha/capita available to marginal household occupants. In fact, 14% of the village population representing larger landholdings on average owns 65 % of the land area within the villages. If a comprehensive land redistribution were undertaken, the average available land per household (including the presently landless community) is 2.4 ha. As can be seen in the data provided here, this would be sufficient to provide for basic food security for the entire village population.

5. Other strategies for increasing food security

5.1 Increasing cropping intensity

As is clear from the data reported in this paper, one potential avenue for enhancing food security is to increase the intensity of cultivation. In Madapur, for example, the cropping intensity was only 118%, owing to the lack of adequate rainfall during certain periods of the year and the limited access to supplemental irrigation as described above. A substantial increase in year-round cropping as is practiced in Inamhongal would make possible the production of greater quantities of grains and pulses. The environmental consequences resulting from the enhanced intensity of cropping (Kuniyal, 2003) must, however, be critically examined and evaluated further.

If the cropping intensity were to be 200% in all villages and under an optimal cropping pattern, this could reduce the land area required to achieve food security within the villages by approximately 1710 ha (of 3625 ha), or 47%. For example, in the case of Madapur, increasing the cropping intensity from 118% to 200% could reduce the required land area under an optimal cropping pattern by nearly half, 47%, of total present cultivable land area.

5.2 Increasing yield

The low yields in the dryland semi-arid regions of southern India can be attributed to what Singh *et al.* (2009) refer to as inadequate traditional management practices coupled with the erratic and highly variable inter-annual precipitation. According to research from the

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), field experiments show that when improved watershed management and natural resource management is integrated in with agriculture, such that land is properly graded and the seedbed prepared so that rainfall has adequate time to infiltrate the soil, the yield of crops can be more than doubled (Singh *et al.*, 2009). If yield were to be doubled, this would reduce the minimum land area that is required to satisfy the human nutritional demands and up to 3 LSUs for a marginal household from 1.8 ha (present) to 0.9 ha (CI = 164%). While the reduction is still not adequate to ensure food security for marginal households, there is a clear nutritional gain from increasing yield.

6. Implications for biofuel production

Given the present difficulty of meeting household food and fodder demand, especially for marginal and small households, it is important to discuss the potential implications of biofuel crops.

There is growing concern that diversion of agricultural land for biomass plantations or the direct conversion of food to fuel could lead to decreased availability of land for food production, particularly among low-income countries (Boddiger, 2007; Hellengers *et al.*, 2008; Ignaciuk *et al.*, 2006; Peters and Thielmann, 2008). Additionally, diversion of land for biofuels crops, when done without proper assessment, can lead to food shortages and increased costs of staple crops such as maize and rice (Koh and Ghazoul, 2008). Nonhebel (2005) also showed that in developing countries there is insufficient land to meet the needs for both food and energy when biomass plantations are substituted for arable land. While this study does not directly assess the impact of land for biofuels conversion, it is apparent from the lack of land to meet basic human and livestock demands that land diversion for biofuel crops could lead to further food insecurity, especially among marginal and small landholdings. While large landholdings could potentially support biofuel production, the reduction in by-products such as fodder would directly impact lower income households who depend on the surplus fodder from larger landholdings.

7. Acknowledgments

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8. Glossary

Variables (capital letters)

$L_{cv,s1}$ = calculated land area of crop variety *cv* in the *kharif* season (hectares)

$L_{cv,s2}$ = calculated land area of crop variety *cv* in the *rabi* season (hectares)

CI_R = cropping intensity ratio

Running index (subscripts)

cv = crop varieties cultivated in the study area: 1. sorghum, 2. wheat, 3. Maize, 4. pearl millet, 5. greengram, 6. redgram, 7. horsegram, 8. bengalgram, 9. groundnut, 10. sunflower, 11. safflower, 12. chilli, 13. onion, 14. cotton.

*s*1 = season in which crops are cultivated: s1. *kharif*

*s*2 = season in which crops are cultivated: s2. *rabi*

R = cropping intensity: 1. Ratio of 2 (or 200%), 2. Ratio of 1.64 (or 164%), 3. Ratio of 1.50 (or 150%).

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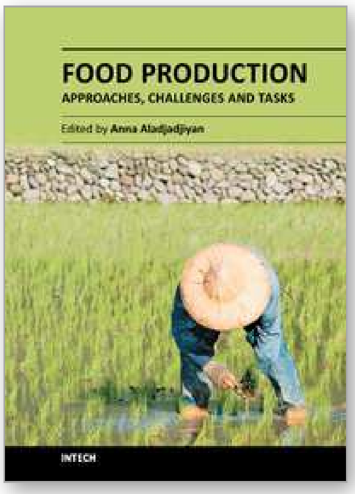

Food Production - Approaches, Challenges and Tasks
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This book is devoted to food production and the problems associated with the satisfaction of food needs in different parts of the world. The emerging food crisis calls for development of sustainable food production, and the quality and safety of the food produced should be guaranteed. The book contains thirteen chapters and is divided into two sections. The first section is related to social issues rising from food insufficiency in the third world countries, and is titled "Sustainable food production: Case studies". The case studies of semi-arid Africa, Caribbean and Jamaica, Burkina Faso, Nigeria, Pacific Islands, Mexico and Brazil are discussed. The second section, titled "Scientific Methods for Improving Food Quality and Safety", covers the methods for control and avoidance of food contaminants. Substitution of chemical treatment with physical, rapid analytical methods for control of contaminants, problems in animal husbandry related to diary production and hormones in food producing animals, approaches and tasks in maize and rice production are in the covered by 6 chapters in this section.