FOOD SECURITY AND ECOLOGICAL FOOTPRINT OF CHITTAGONG HILL TRACTS IN BANGLADESH

B. K. Bala*,
M. A. Hossain** and
S. Majumder***

ABSTRACT

This paper presents food security and ecological footprint of the Chittagong Hill Tracts (CHT) in Bangladesh. To estimate food security and ecological footprint, primary and secondary data were collected and a multistage sampling was designed for selecting the farm households from the three districts of the Hill Tracts of Chittagong. A quantitative method for computation of food security was used. To estimate the environmental sustainability at upazila (sub-district) levels, a method of computation of ecological footprint developed by Wackernagel was used. Multiple logistic regression models were fitted to data on food security of the farmers in CHT to identify the factors affecting food security at household levels in CHT. Overall status of food security at upazila levels was found to be good for all the upazilas except Rangamati sadar and the best was found in Alikadam. Environmental status in the Hill Tracts of Chittagong was poor for all the upazilas. Household food security was found to be significantly ($p<0.05$) affected by farm size, education, professions, crops cultivated (jhum and tobacco), distance from market and transition from jhum to horticulture. This study supports transition from jhum to horticulture crops for increased food security and banning tobacco cultivation to avoid deforestation in CHT.

Keywords: *Food security, Ecological footprint, Shifting agriculture, Logit model, Hill Tracts of Chittagong.*

1. INTRODUCTION

Chittagong Hill Tracts (CHT) are the only extensive hilly area in Bangladesh, located in the south eastern of the country. The area of the Chittagong Hill Tracts is about 13,184 sq. km., of which 92% is highland, 2% medium highland, 1% medium lowland and 5% homestead and water bodies. The total population of CHT is 13,31,996, out of which about 51% are tribal people.

Agriculture is the main source of livelihood for this population. Non-farm income opportunities are very limited and, in some areas, non existent. The tribal population here is the most disadvantaged group in Bangladesh. Shifting agriculture is still the cultivation system in this region, with little impact of different plans and programs to promote the agricultural land use patterns. As a result, the tribal populations are suffering from food insecurity and shifting agriculture has led to indiscriminate destruction of forest for food resulting ecological degradation.

Promoting sustainable development in uplands of Chittagong Hill Tracts poses important challenges. These upland areas are remote, and are mostly inhabited by many ethnic minorities. The majority of the ethnic minorities are Chakma (48%) and Marma (28%). The incidence of poverty is very high. To meet the livelihood needs, upland farmers often use unsustainable land use practices. Uplands are essentially caught in a vicious cycle of poverty, food insecurity and environmental degradations. Land use practices in uplands not only degrade the resource-base but also negatively impact on the livelihoods and resource bases downstream. Wider environmental impacts also occur in the form of reduced biodiversity, reduced ability of the ecosystem to regulate the stream flow and reduced carbon sequestration.

Food security is a social sustainability indicator, and most commonly used indicators in the assessment of food security conditions are food production, income, total expenditure, food expenditure, share of expenditure of food, calorie consumption and nutritional status etc. (Riely et al., 1999). Accounting tools for quantifying food security are essential for assessment of food security status and also for policy planning for sustainable development. Several studies have been reported on food security in terms of per capita food availability in Bangladesh (Begum, 2002), pattern of household food consumption and causes of food insecurity (RDRS, 2005); and access and utilization of food and the issues of food and nutritional security (Mishra and Hossain, 2005). These studies give descriptive statistics of the food security. Bala and Hossain (2010) reported a quantitative method of computation of food security. Several studies have been reported to identify the determinants of food security at household level using logistic models (Babatunde et al., 2007; Haile et al., 2005; Faridi and Wadood, 2010 and Sikwela, 2008). But no study has been conducted to identify the determinants of household food security in CHT.

Ecological footprint is an ecological stability indicator and it is a synthetic indicator used to estimate a population s impact on the environment; it quantifies total terrestrial and aquatic area necessary to supply all resources utilized and to absorb all emissions produced in a sustainable way. Apart from analyzing

* Universiti Putra Malaysia. Email: bkbalabau@yahoo.com ** Bangladesh Agricultural Research Institute, Bangladesh.
*** Bangladesh Agricultural University, Bangladesh

the present situation, ecological footprint provides framework of sustainability planning in the public and private scales. Several studies have been reported on the applications of ecological footprint during past decade to address environmental sustainability (Wackernagel et al., 1999; Monfreda et al, 2004; Zhao et al., 2005; Medved, 2006; Chen and Chen, 2006; Bagliani et al., 2008; Niccolucci et al., 2008; Bala and Hossain, 2010). The ecological footprint has been jointly used combining emergy analysis to evaluate ecological footprint for regional level (Zhao et al., 2005) and national level (Chen and Chen, 2006) as well as to assess ecological footprint and biocapacity (Monfreda et al., 2004; Medved, 2006; Bagliani et al., 2008).

The purpose of this paper is to estimate the present status of food security and environmental degradation of the Chittagong Hill Tracts of Bangladesh at upazila (sub-district) levels and develop logit models to identify the factors affecting food security at household levels.

2. MATERIALS AND METHODS

2.1 Sample Survey and Data Analysis

A multi-stage sampling was designed for selecting the farm households from the Hill Tracts of Chittagong consisting of Bandarban, Rangamati and Khagrachhari districts. The sampling framework consisted of primary sampling units of the district, secondary sampling unit of upazila, pre-ultimate sampling units of the village and ultimate sampling of individual households. The ultimate sampling units from each of the villages were selected by stratified random sampling method with proportional allocation, where farm categories were considered as the strata. Multi-stage sampling procedure designed in this study was used to select a total of 1,779 households. In addition, a Focus Group Discussion was held with the Sub-Assistant Agricultural Officers of 10 Blocks of Khagrachhari Sadar Upazila on jhum cultivation, on 16 April 2009, in the Khagrachhari Upazila Agricultural Extension Office. Data on population, crop, tobacco, livestock and forestry were collected to estimate the present status of food security at upazila levels in Bangladesh from upazila office of Government Department of Statistics, Agriculture, Fishery and Livestock. Information collected using multi stage stratified sampling was used to develop logit models to identify the factors affecting household food security.

2.2 Computation of Food Security

The US Department of Agriculture (USDA) evaluated food security based on the gap between projected domestic food consumption and a consumption requirement (USDA, 2007). All food aid commodities were converted into grain equivalent based on their calorie content. Based on the USDA concept, the food security is defined as:

Food Security = (Food available from different sources and also equivalent food from different sources - Food requirement) / Food requirement Eq. (1)

The total food intake proposed is 2,345 kcal/cap, which midway between the values suggested by WHO (2,310 kcal) and FAO (2,400 kcal). The proposed 2345 kcal is equivalent to 1.357 kg of rice based on price. All food aid commodities were converted into grain equivalent based on economic returns (price) to compute the food security. Based on this concept the food security is computed as (Bala and Hossain, 2010):

Food Security = ((Food available from crops including equivalent food from income of tobacco + Food available from aquaculture and equivalent food from income of aquaculture + Food available from livestock and equivalent food from income of livestock + Food available from forestry and equivalent food from income of forestry) Total food requirement) / Total food requirement Eq. (2)

Positive food security means surplus food and negative food security means shortage in food supply to lead healthy life.

2.3 Computation of Ecological Footprint and Biological Capacity

Ecological footprint represents the human demands, taking into account the production and supply of resources (energy, food and materials) and assimilation of the wastes (in all forms) generated by the analyzed system. Ecological footprint of a given population is the total area of productive land and water required to produce all the resources (energy, food and materials consumed), and to absorb the waste generated by that population of a region or nation using prevailing technology and resource management practices. The ecological footprint calculation is based on average consumption data converted into the usage of productive lands. The bioproductive land is divided into 6 categories according to the classification of the World Conservation Union: (1) cropland; (2) grazing land; (3) forest; (4) fishing ground; (5) build-up land; and (6) energy land.

Total ecological footprint is the sum of the ecological footprints of all categories of land areas which provide for mutually exclusive demands on the bio-sphere. Each of these categories represents an area in hectares, which is then multiplied by its equivalence factor to obtain the footprint in global hectares. One global hectare is equal to 1 hectare with productivity equal to the average of all the productive hectare of the world. Thus, one hectare of highly productive land is equal to more global hectares than one hectare of less productive land. The ecological footprint can be expressed as (Monfreda et al., 2004):

Footprint (gha) = Area (ha) × Equivalence Factor (gha/ha) Eq. (3)

where Equivalence Factor = the world average productivity of a given bioproductive area / the world average potential productivity of all bioproductive areas.

Equivalence factor represents the world average productivity of a given bioproductive area relative to the world average potential productivity of all productive areas and it is the quantity of global hectares contained within an average hectare of cropland, build-up land, forest, pasture or fishery.

An important part of the ecological footprint analysis of a region or zone is represented by the calculation of its Biological Capacity (Biocapacity). This takes into account the surfaces of ecologically productive land located within the area under study. Biological capacity represents the ecologically productive area that is locally available and it indicates the local ecosystems potential capacity to provide natural resources and services. Biological capacity is the total annual biological production capacity of a given biologically productive area. Biological capacity can be expressed as (Monfreda et al., 2004):

Biocapacity (gha) = Area (ha) × Equivalence Factor (gha/ha) × Yield factor Eq. (4)

where Yield factor = Local yield/ global yield

Total biocapacity is the sum of all bioproductive areas expressed in global hectares by multiplying their area by the appropriate equivalence factor and the yield factor specific to that country/locality. Biological capacity can be compared with the ecological footprint, which provides an estimation of the ecological resources required by the local population. The ecological status is expressed as the difference between biocapacity and ecological footprint. A negative ecological status (BC < EF) indicates that the rate of consumption of natural resources is greater than the rate of production (regeneration) by local ecosystems (Rees, 1996). Thus, an ecological deficit (BC < EF) or surplus (BC > EF) provides an estimate of a local territory s level of environmental sustainability or unsustainability. This also indicates how close is the specific area to sustainable development.

2.4 Logit Model for Household Food Security

Logit model is a form of regression which is used when the dependent variable is categorical and independent variables could be of any type. It can be used to predict a dependent variable on the basis of continuous and/or categorical independent variable: to determine the effect size of the independent variables on the dependent; to rank the relative importance of independent variables; to assess interaction effects; and to understand the impact of covariate control variables.

Let Yi denote the food security at household level, where Yi =1 if ith household is food secured and Yi = 0 if not. Also let the k independent variables $X1_i$, $X2_i$, , Xk_i which are either categorical ones coded as dummy variables, such as farm category, profession, training status, etc. or continuous, such as road distance, years of schooling, etc. are measured for each of the n households. In the linear logistic regression model, the dependence of the probability of success on independent variables is assumed to be (Gujrati and Sangeetha, 2007):

$$P_i = \frac{\exp(\sum_{j=0}^{k} \beta_j X_{ij})}{1+\exp(\sum_{j=0}^{k} \beta_j X_{ij})} \qquad \text{Eq. (5)}$$

$$1-P_i = \frac{1}{1+\exp(\sum_{j=0}^{k} \beta_j X_{ij})} \qquad \text{Eq. (6)}$$

where $X_{0j} \equiv 1$, β_0= intercept and (j=1,2,...,k) are the unknown coefficients.

Equations (5) and (6) look complicated; however, the logarithm of the ratio of P_i and $(1-P_i)$ which is called the logit to Pi turns out to be a simple linear function fo the X_{ij} that is:

$$\lambda_i = \log it(P_i) = \log_e \frac{P_i}{1-P_i} = \sum_{j=0}^{k} \beta_j X_{ij} = \beta_0 + \sum_{j=1}^{k} \beta_j X_{ij} \qquad \text{Eq. (7)}$$

λ_i is also called the logistic transform of P_i and the equation (7) is known as a linear logistic regression model.

The parameters of the logit model are estimated based on the maximum likelihood method suggested by Cox (1970). This model calculates the changes in the log odds of the dependent, and not the changes in the dependent itself as OLS regressions would.

3. RESULTS AND DISCUSSIONS

3.1 Food Security and Ecological Footprint at Upazila Level

Figure-1 shows the food security status in nine upazilas of Bandarban Sadar, Alikadam, Ruma, Rangamati Sadar, Barkal, Kaptai, Khagrachhari Sadar, Mahalchhari and Dighinala. Bandarban Sadar (+37.10%), Alikadam (+141.03%), Ruma (+89.67%), Barkal (+6.52%), Kaptai (+8.71%), Khagrachhari Sadar (+5.04%), Mahalchhari (+51.19%) and Dighinala (+36.73%) have positive food security status, and, only Rangamati Sadar (-24.43%) has negative food security status. This implies that Bandarban Sadar, Alikadam, Ruma, Barkal, Kaptai, Khagrachhari Sadar, Mahalchhari and Dighinala are food surplus and Rangamati Sadar are food deficit upazilas.

Figure-2 shows the contributions of crop and horticulture to food security in the nine upazilas of Bandarban Sadar, Alikadam, Ruma, Rangamati Sadar, Barkal, Kaptai, Khagrachhari Sadar, Mahalchhari and Dighinala. Mahalchhari (77%) has the largest contribution to food security from crop followed by Dighinala (64%) and Khagrachhari Sadar (59%) and these upazilas are crop dominated while Bandarban Sadar (18%) has the largest contribution to food security from horticulture followed by Kaptai (16%) and Khagrachhari Sadar (16%).

Figure-3 shows the ecological footprint in the nine upazilas of Bandarban Sadar, Alikadam, Ruma,

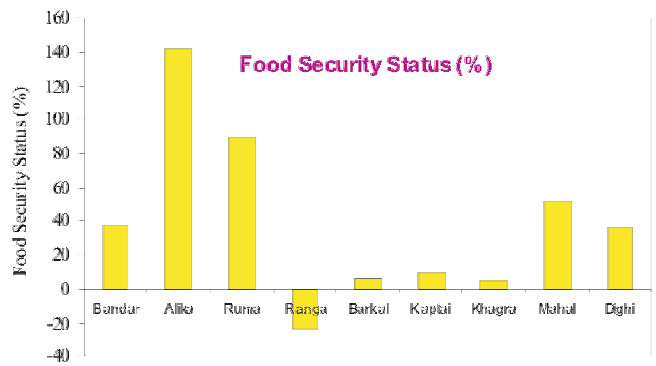

Figure-1: Food Security Status of Different Upazilas

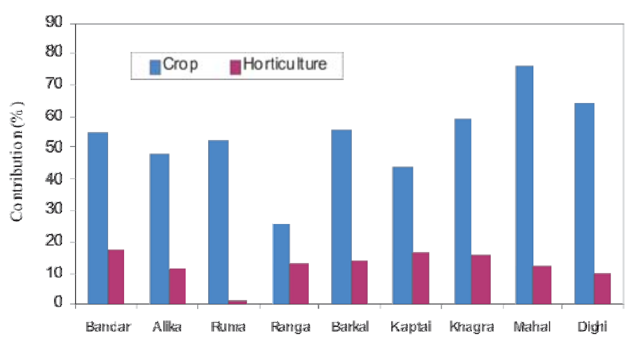

Figure-2: Contributions of Crop and Horticulture to Food Security of Different Upazilas

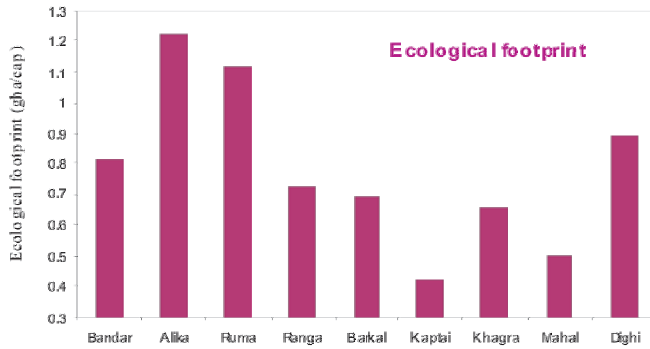

Figure-3: Ecological Footprint of Different Upazilas

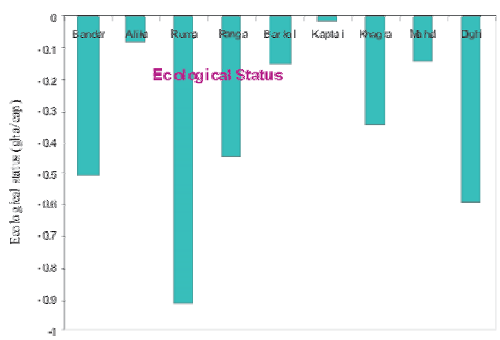

Figure-4: Ecological Status of Different Upazilas

Rangamati Sadar, Barkal, Kaptai, Khagrachhari Sadar, Mahalchhari and Dighinala. The largest ecological footprint is at Alikadam (1.223 gha/cap) followed by Ruma (1.119 gha/cap) and the lowest ecological footprint is at Kaptai (0.426 gha/cap). This implies that Alikadam and Ruma have suffered serious environmental degradation and Kaptai is the least suffered upazila.

Figure-4 shows the ecological status in the nine upazilas of Bandarban Sadar, Alikadam, Ruma, Rangamati Sadar, Barkal, Kaptai, Khagrachhari Sadar, Mahalchhari and Dighinala. The ecologial status of all the upazilas is negative which implies that these upazilas are facing environmental degradation. The ecological status of all the upazilas is deficit because a large amount of wood are used in the kiln for tobacco processing in addition to a large amount of leaves and trees are burnt out for the cultivation of Jhum. Bala and Hossain (2010) assessed the ecological status in the nine upazilas of the coastal zone of Bangladesh, and found that only two upazilas are ecologically surplus and the rest of the five upazilas are ecologically deficit. Wackernagel et al. (1999) also reported that the ecological status for Bangladesh as a whole is -0.20 gha/cap. The average ecological status (-0.2) of Bangladeesh is marginally deficit, but the ecological status (-0.914) of Ruma is 4.5 times of the national average of Bangladesh and needs policy level commitment and programs to arrest the growth and reduce environment degradation.

3.2 Food Security at Household Levels

The results of multiple logit regression models fitted to the data on household food security of the farmers in CHT are shown in Table-1. The logit analysis shows that food security of large farmers is significantly ($p<0.05$) higher than that of other farmers. Large farmers are 1.41 times more likely to be food secured than that of other farmers. Food security appears to be significantly ($p<0.05$) lower among the non-tribal farmers than the tribal ones. The odds ratio shows that there is a 34 per cent decrease in the risk of food insecurity among the tribal farmers as compared to that of non-tribal ones.

A significantly ($p<0.05$) lower food security is found among the farmers whose professions are only agriculture than the farmers having professions like

Table-1: Results of multiple logistic regression model fitted to the data on food security of the farmers in CHT

Variable	Category	Estimated Coefficient $(\hat{\beta})$	SE $(\hat{\beta})$	Wald's P	Odds Ratio
Farm category	Large Other (ref.)	0.340* -	0.157	0.030	1.41
Inhabitant	Non-tribal Tribal (ref.)	-0.411* -	0.193	0.033	0.66
Years of Schooling		0.019	0.012	0.128	1.02
Profession	Agriculture Non-agriculture (ref.)	-0.247* -	0.109	0.023	0.78
Road Distance		-0.046	0.031	0.139	0.96
Family Size		-0.043	0.023	0.062	0.96
Jhum Cultivation	Yes No (ref.)	-0.448*** -	0.113	0.000	0.64
Training Status	Yes No (ref.)	0.136	0.136	0.316	1.15
Micro- Credit	Formal Informal Both No (ref.)	0.099 0.126 0.672 -	0.119 0.201 0.412	0.403 0.532 0.103	1.10 1.13 1.96
Extension Service	Yes No (ref.)	0.086 -	0.139	0.535	1.09
NGO Service	Yes No (ref.)	-0.007 -	0.163	0.967	0.99
Rice Cultivation	Yes No (ref.)	0.008 -	0.109	0.939	1.01
Commercial Fruits	Yes No (ref.)	-0.132 -	0.106	0.210	0.876
Livestock	Yes No (ref.)	-0.057 -	0.126	0.651	0.944
Tobacco Cultivation	Yes No (ref.)	2.510*** -	0.325	0.000	12.30
-2 Log Likelihood = 2302.744		Model Chi-Square Value = 161.275 (p<0.001)			

* and *** indicate significance at p<0.05 and p<0.001

service, business, labour, service+agriculture and business+agriculture and labour+agriculture. The odds ratio Table-1 implies that there is 22 percent decrease in the risk of food insecurity among the farmers having foresaid professions than that of the farmers whose professions are only agriculture.

Food security is significantly (p<0.001) lower among the jhum cultivators than those of the farmers who do not practice shifting cultivation. The risk of food insecurity decreases by 36 percent if the farmers involve themselves with other agricultural activities like rice cultivation, forestry and horticulture instead of shifting cultivation. The farmers who produce tobacco are highly significantly (p<0.001) food secured than the others. The odds ratio Table 1 indicates that tobacco cultivators are about 12 times more likely to be food secure than that of tobacco non-cultivators.

The results of multiple logistic regression models fitted to the data on transition from *Jhum* to horticulture are shown in Table-2. The transition from *jhum* to horticulture of the large farmers is significantly (p<0.01) higher than those of other farmers. Large farmers are 31.48 times more likely to transit from *jhum* to horticulture than that of other farmers. Education exerts a significantly (p<0.05) positive association with the transition from *jhum* to horticulture. A significantly higher transition is observed among the farmers of better educational qualification than that without any such qualification. The impact of market distance on the transmission from *jhum* to horticulture appears significant (p<0.05) and its negative sign in Table-2 indicates that better transition occurs for lower market distance.

Table-2: Results of multiple logistic regression model fitted to the data on transmission from jhum to horticulture

Variable	Category	Estimated Coefficient $(\hat{\beta})$	SE $(\hat{\beta})$	Wald's P	Odds Ratio
Farm category	Large Other (ref.)	3.449**	1.010	0.001	31.48
Years of Schooling		0.060*	0.027	0.028	1.06
Market Distance		-0.028*	0.012	0.015	0.97
Extension Service	Yes No (ref.)	0.289	0.188	0.125	1.34
Family Labour		0.056	0.078	0.476	1.057
-2 Log Likelihood = 719.805		Model Chi-Square Value = 64.001 (p<0.001)			

Note: * and ** indicate significance at p<0.05 and p<0.01

4. POLICY IMPLICATIONS

Agricultural systems of the Hill Tracts of Chittagong are still traditional with marginal yield i.e. jhum cultivation resulting in soil erosion and an expanding coverage of tobacco cultivation along banks of the hilly rivers which results in rapid depletion of the nearby reserve forests for kilning the tobacco. These traditional agriculture and expanding coverage of tobacco cultivation are threats to the environment and even this rapid expansion of tobacco cultivation may cause the total destruction of the reserve forests of the Hill Tracts of Chittagong within a short period of time. The findings of this study analysis suggest the following policy implications:

Fruit trees with other horticultural crops control soil erosion and landslides. Tobacco cultivation should be banned deforestation and extension service. Infrastructural development for access to market and development of marketing channels for agro products need promotion of environmentally sustainable and economically viable agricultural systems.

5. CONCLUSIONS

Food security and environmental degradation in terms of ecological footprint of nine upazilas of three districts of the Hill Tracts of Chittagong are estimated.

The overall status of food security at upazila level is good for all the upazilas (5.04% to 141.03%) except Rangamati Sadar (-24.43) and the best is the Alikadam upazila (141.03%).

The environmental status in the CHT region is poor for all the upazilas. The environmental status in the CHT region has degraded mainly due to jhum and tobacco cultivation.

Household food security is found to be significantly (p<0.05) affected by farm size, education, professions, crops cultivated (jhum and tobacco), distance from market and transition from jhum to horticulture. Finally, gradual transition from jhum to horticulture crops for increased food security and banning tobacco cultivation to avoid deforestation in CHT are logical choices for sustainable development.

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REFERENCES

- Babatunde, R.O., Omotesho, O.A., and Sholotan, O.S., 2007. Factors influencing food security status of rural farming households in North Central Nigeria. Agricultural Journals, 2(3), pp. 351-357.
- Bagliani, M., Galli, A., Niccolucci, V., and Marchettini, N., 2008. Ecological footprint analysis applied to a sub-national area: The case of the Province of Siena Italy). Environmental Management, 86(2), pp.354-364.

- Bala, B.K., and Hossain, M.A., 2010. Food security and ecological foot print of the coastal zone of Bangladesh. Environment, Development and Sustainability, 12, pp.531-545.
- Begum, S., 2002.Proceedings of the APO seminar on role of rural women in food security in Asia and the Pacific held in Thailand from 21-25 August 2000 Asian Productivity Organization Tokyo, Japan.
- Chen, B., and Chen, G.Q., 2006. Ecological footprint accounting based on energy- A case study of the Chinese society. Ecological Modeling, 198, pp. 101-114.
- Cox, D.R. 1970. Analysis of Binary Data. Methuen & Co., London.
- Faridi, R., and Wadood, S.N., 2010. An econometric assessment of household food security in Bangladesh. The Bangladesh Development Studies, 33(3).
- Gujrati, D.N., and Sangeetha. 2007. Basic Econometrics. Tata McGraw, New delhi, India.
- Haile, H.K., Alemu, Z.G., and Kudhlande, G.2005. Causes of household food insecurity in Koredegaga Peasant Association, Oromiya Zone, Ethiopia. Working paper. Department of Agricultural Economics. University of the Free State.
- Medved, S., 2006. Present and future ecological footprint of Slovenia- The influence of energy demand scenarios. Ecological Modeling, 192, pp. 25-36.
- Mishra, U., and Hossain, S.A.K.,2005. Current food security and challenges: Achieving 2015 MDG hunger milepost. Food security in Bangladesh. Paper presented in the national workshop. October 19-20,2005, Dhaka Bangladesh. pp 01-06
- Monfreda, C., Wackernagel, M., and Deumling, D.,2004. Establishing national natural capital accounts based on detailed ecological footprint and biological capacity assessment. Land Use Policy, 21, pp. 231-246.
- Niccolicci, V., et al., 2008. Ecological footprint analysis applied to the production of two Italian wines. Agriculture, Ecosystems and Environment, 128, pp. 162-166.
- RDRS. 2005. A report of survey on food security and hunger in Bangladesh. ISBN 984-32-2562-7.
- Rees, W.E. 1996. Revisiting carrying capacity: area-based indicators of sustainability. Population and Environment, 17, pp.195-215.
- Riely, F., et al., 1999. Food security indicators and framework for use in the monitoring and evaluation of food aid programs. Food and Nutrition Technical Assistance Washington DC.
- Sikwela, M.M., 2008. Determinants of household food security in the semi-arid areas of Zimbabwe: a case study of irrigation and non-irrigation farmers in Lupane and Hwange districts. MS thesis, University of Fort Hare, South Africa.
- USDA. 2007.Food Security Assessment. USDA economic research Service. Appendix- Food Security Model: Definition and Methodology.GFA-19. Washington DC.
- Wackernagel, M., et al., 1999. National natural capital accounting with the ecological footprint concept. Ecological Economics, 29, pp. 375-390.
- Wackernagel, M., and Rees, W.E., 1996. Our ecological footprint: Reducing human impact on the earth New society Gabrioala BC Canada. ISBN 1-55092-251-3.
- Zhao, S., Li, Z.Z., and Li, L., 2005. A modified method of ecological footprint calculation and its application. Ecological Modeling, 185, pp. 65-75.