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Population pressure, agricultural intensification and changes in rural systems in Bangladesh

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Abstract

Sustainable agricultural growth is the key to rural system changes that include changes in rural bio-physical environment, economic infrastructure and social conditions. The present study has examined the temporal changes in 18 selected indicators of rural systems in Bangladesh during the period 1975–2000, and explored the influences of demographic, market forces, environmental, institutional and technological factors inducing and mediating such changes. An analysis of 64 district level published census data showed significant increase in agricultural intensity, cropping patterns, land productivity and farm income; decline in labor and technological productivities; and major improvement in rural housing, economic and social conditions during this period. Spatially, major agricultural growth and rural development were observed in districts with high population density, less constrained environments, and better access to markets, irrigation canals, and capital loans.
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Keywords: Bangladesh; Agricultural productivity; Rural development; Rural systems change

1. Introduction

Bangladesh, a country of 147 million (UNPRB, 2006), is dominated by a smallholder intensive subsistence agricultural economy in which agricultural growth is seen as the key to rural socio-economic development.[1] Agricultural growth involves intensive (frequent) cultivation of land by using improved technologies (Turner and Doolittle, 1978). It increases total farm production and productivities (output per unit) of land and labor inputs; hence, it ensures food security, and increases farmers' economic opportunities and their aspiration levels toward material gains to lead a better life. Sustained agricultural growth induces rural system change that includes changes in bio-physical environment (land use/land cover), economic infra-structure (cropping intensity, land, labor, and technological productivity, farm income), and social conditions (literacy, housing, transport) in rural areas. Rural system changes represent farmers' production and social behavior (Ruttan, 1984).

Over the past 30 years, in the midst of myriad environmental and institutional constraints, Bangladesh population has doubled; its food and commodity production increased; and its rural areas have experienced discernible changes in socio-economic conditions. For balanced agricultural and rural development planning, in which agricultural growth and smallholder's socio-economic well-being would continue simultaneously (as per the national standard), the level of agricultural growth and rural socio-economic change should be understood in the context of demographic, market, environmental, institutional, and technological factors that configure them.

Existing studies on Bangladesh agriculture and rural development have examined the conditions of micro-level

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[1] Over 80% of Bangladeshi rural households are smallholders (<1 ha) who practice intensive subsistence farming. In an intensive subsistence farming system, farmers use family labors and frequently cultivate their land and produce food crops primarily for consumption, and some cash crops for sale to meet social needs.

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agricultural intensification and change (Ali, 1987, 1995; Turner and Ali, 1996); the public policy and political economic issues of rural development, micro-credit, and energy systems; and the role of women in agriculture and socio-economic development (Ahmed et al., 2001a,b; Amin et al., 1994; Bayes, 2001; Biswas et al., 2001; Blair, 1985; Hye, 1989; Matin and Hulme, 2003; Rahman, 1996a,b; Rahman, 1999; Sharif, 1992). These studies have not explored the nature and causes of rural system changes. An understanding of these changes may have significant policy implications.

The present study examines the nature and determinants of rural system changes in Bangladesh between 1975 and 2000. Based on 18 selected indicators of land use/land cover changes, agricultural growth and rural development, the study aims to construct an index to measure the degree of rural systems change, and to examine the effects of population growth, market price incentives, environmental constraints, technology, political economy and institutional forces on such changes. The study examines 64 administrative districts' census data; and thus, its results have much larger implications for national economic development planning.

2. Conceptual framework

The study is based on the premises that agricultural change causes rural system changes; that factors affecting agricultural intensification also affect the rural systems; and that the spatial patterns of agricultural growth and rural socio-economic change are reflective of household production and social behavior. Under these premises, the factors influencing agricultural change are identified at the onset of this study. Theories explaining agricultural change center around two ideal conditions: population pressure and market price incentives – both induce agricultural intensification but with different rational and production goals. Following Ester Boserup (1965), the population pressure theory contends that all other conditions being equal, growing population density induces farmers to cultivate their land more frequently via changing technology, cropping schedules, cultivars, and labor inputs in order to secure the minimal subsistence production of consumption crops by way of least risk and leisure maximizing strategies (Boserup, 1965; Chayanov, 1966; Turner et al., 1977, 1993). Frequent cultivation increases total food production and ensures household food security. Theodore Schultz (1964) proposed the commodity demand thesis that asserts that growing market price of commodity crops induces farmers to increase the frequency and acreage of cultivation of those crops (Mellor, 1969; Schultz, 1964; Turner and Brush, 1987; Wharton, 1969). Increased commodity production increases farm income; compensates economic loss incurred from falling market price of consumption crops; improves socio-economic well-being of the family; and improves soil quality through crop rotations (Laney, 2002).

The critics of demand based theories question the validity of long lasting positive impacts of population growth and market force on agricultural growth and rural development. They pointed out that population growth causes rapid urbanization and conversion of farmland, and increases landlessness; it demands over-cultivation of farmland and massive deforestation that accelerates land degradation via rapid soil erosion and depletion of water and soil nutrients. Land degradation reduces crop yield, and increases poverty, and thus retards agricultural growth and rural development (Bartelmus, 1986; Durning, 1989; Holmberg, 1991; Lipton, 1977; Lonergan, 1993; Mwalyosi, 1992; Shaw, 1989; Scherr, 2000). Similarly, market force demands frequent cultivation of land, and clearing forest which fosters soil erosion and depletion of water and soil nutrients (Zhao et al., 1991). Commercialization of crops (e.g., shrimp) using higher dosage of chemicals also leads to land, soil and environmental degradation (Ali, 2006).

Considering both positive and negative impacts of population growth and market forces, it becomes apparent that a carefully monitored population growth and market incentives are preconditions and powerful driving forces behind agricultural intensification and rural development. However, the Third World literature informs us that traditional smallholders are neither pure subsistence nor pure market farmers. Instead, they are mixed or dual farmers who produce for direct consumption and increasingly engage in production for the market; and their dual production behavior is mediated by environmental, techno-managerial, political economic and institutional conditions under which they operate.

Environmental constraints such as flood, drought, soil salinity and poor land quality limit frequent cultivation of high demanding crops and lower their yield, thereby stymie agricultural growth and rural development (Brookfield, 1972; Brush and Turner, 1987). Under uniform demand levels, the high constraining environments give rise to the high technical labor and input intensive farming systems in which both cropping intensity, land and labor productivities are lower than in low and medium constrained environments (Ali, 1987; Metzner, 1982; Padoch, 1985; Rigg, 1985; Turner et al., 1977; Vassey, 1979).

The role of technology in agricultural change can be posited in two ways (Grigg, 1982, 1992). Treated exogenously, an improved technology input reduces the severity of environmental constraints and drives agricultural growth. Viewed endogenously, it allows frequent cultivation and increases crop yield. However, technological change must wait until the threshold capacity of the existing technology is reached under the stress exerted by current population pressure, market forces, and environmental constraints (Hayami and Rutton, 1985; Pingali et al., 1987). While technological change is required for agricultural growth, its negative impacts on soil and water resources can also impede agricultural growth. Excessive uses of chemical fertilizers and low-lift pump irrigation have increased soil acidity, salinity, and degraded soil chemical properties which in turn reduced crop yield in the tropics (Ali, 2004; Douglas, 1994).

Political economic factors focus on the household socioeconomic structure that controls the farmers' differential power and access to land resources (Bassett, 1988; Blaikie and Brookfield, 1987). For Third World developing countries, farm size is the key political economic factor that dictates farmers' land use decisions; smallholders allocate more land to consumption crops to achieve food security while large holders allocate more land to produce commodity crops for the market. Agricultural intensity and productivity vary inversely with farm size (Boyce, 1987; Griffin et al., 2002). While smallholders are most efficient and cultivate their land most intensively, over-cultivation accelerates soil erosion, depletion of water and soil nutrients that lead to decline in crop yield and thus affects the farmers' household economy (Lipton, 1977).

Institutional factors are involved in the negotiation of farmers' access to capital resources as well as of policies and factor markets impinging on the smallholder (Brush and Turner, 1987; Bryant, 1992; Hershkovitz, 1993; Leinbach et al., 1992; Sheridan, 1988; Zimmerer, 1996). In Bangladesh, for example, institutional supports such as government and non-government (NGO) sponsored distribution of capital loans, price subsidies on farm inputs, work for food programs to construct flood control embankment and excavation of irrigation canals eventually have benefited agricultural growth and rural development (Ahmad, 1985; Boyce, 1987; Yunus, 2000).

The driving power of population pressure and market force on agricultural change notwithstanding, the two ideal demand-based theories offer an important conceptual tool to examine agricultural change. However, the issue of duality in smallholder production strategy, and the mediating power of environment, technology, political economic and institutional forces on farmers' land use decisions have demanded a merger of the two ideal models, and an expansion of the new hybrid model beyond its simplistic assumptions. Elsewhere, Turner and Ali (1996) formulated and tested the induced intensification thesis of agricultural change to account for the duality of production, and to capture the mediating influence of environment, technology and political economy by using temporal data collected from 256 Bangladeshi smallholder households. The thesis

Fig. 1. Administrative districts and major physical regions of Bangladesh.

asserts that smallholders respond equally to growing household population density and market incentives, and increase cultivation of food and commodity crops via changing crops and techno-managerial skills. Farmers' land allocation decision is mediated by the level of constraints exerted by the environment, techno-managerial skills available to combat those constraints, and political economic conditions under which they operate. Turner and Ali (1996) tested the thesis using a conceptual model that linked two demand based input variables, namely as household population density (PDEN), and farmland under commodity crops (MARK), to two output variables such as cropping intensity (CINT) and land productivity (PROD) via three sets of mediating status variables. The mediating variables were: percent of household land under homestead (HOMES) and cropland (FARM), and the size of cultivated plots (PLOT) both representing the household political economy; percent of land under four levels of flood depth (QL II–V), and an environmental constraint index accounting the percent of farmland affected by flood, drought, and salinity (ENVINDEX) representing the environmental constraints; and percent of land irrigated (IRIG) by low-lift pumps, amount of chemical fertilizer (TECH), and number of technical labor used in farming (TLAB) as technology input to combat environmental constraints. In this paper, with major modifications in data and variable types, the induced intensification thesis is taken as a theoretical framework to study agricultural and rural system changes in 64 districts in Bangladesh during 1975 and 2000 (Fig. 1).

3. Attributes of agricultural growth and rural systems change in Bangladesh

3.1. Population pressure

During 1975–2000, Bangladesh population has grown from 71.5 million to 133.5 million (BBS, 1975–2001). Population grew >100% in Dhaka, Chittagong, and Bandarban districts; between 50–100% in northeastern and western districts; and <50% in southern districts. High population density (>1443 people/km^2) in districts under Dhaka, Chittagong, Comilla, Tangail, Mymensigh, Pabna, Rajshahi, and Faridpur; low density (<843 people/km^2) in Khulna, Patuakhali, Bandarban and Rangamati regions; and moderate density (844–1499 people/km^2) in rest of the country characterized the population distribution (Fig. 2a). High population densities are found in metropolitan cities and administrative headquarters with major educational institutions, port and industrial activities, whereas low population densities are found in districts with severe flooding, excessive dryness, salinity, and mountain topography.

3.2. Growing landlessness

The rural population of Bangladesh is organized into large (>3 ha), medium (1–3 ha), small (0.2–1 ha), and functionally landless (<0.2 ha) households. During the 1977 and 1996 Agricultural Census years, the average per capita arable land has declined from 0.13 ha to 0.09 ha indicating growing landlessness (BBS, 1977, 1996). Landlessness increased due to rapid population growth, loss of farmland to urban and settlement expansion, effectiveness of the law of inheritance, riverbank erosion, active land market and sale of farmland to meet social expenses and to purchase farm inputs and food (Khan, 2004). During this period, the number of large, medium and smallholder households declined, respectively, by 77%, 73% and 31%, resulting a staggering ten fold increase in the number of functionally landless households, who now account 56% of all rural households but control only 6% of total farmland in the country (Table 1). Spatially, districts in Dhaka, Chittagong, Rajshahi and Comilla regions have experienced >40% increase in smallholder and landless households, and all other districts have experienced <40% in this categories (Fig. 2b).

3.3. Changing political economy

The farmers of Bangladesh are categorized as owners (64%), owner-cum-tenants (24%), and tenants (10%) (BBS, 2000, p. 218). The present political economy is a result of the first *tenurial land reform* of 1950 under the East Bengal State Acquisition and Tenancy Act that abolished the century-long landlordism (zaminders) created by the Mugol and British rulers to collect revenues from tenant and sharecroppers. Landlordism was seen as the key obstacle to agricultural growth (Byres, 2004, 3; Jannuzi and Peach, 1980; Kabir, 1969). The reform allowed the *zaminders* to retain up to 33 acres (maximum ceiling) of land under their possession to cultivate as "owner-operators" and rent out land to smaller owners and sharecroppers who were then transformed into owner-cum-tenant and tenant farmers. The provision of 33 acre land holding ceiling formed the basis of *redistributive land reform* that allowed the Government to take excess farmlands from large holders and redistribute them among landless and smallholders for more intensive cultivation by using family labor. Its aim was to reduce unemployment and increase land productivity to achieve agricultural growth and rural development (Byres, 2004; Griffin et al., 2002).

3.4. Growing market opportunities

Traditionally, Bangladeshi farmers had produced jute, sugarcane, legumes, fruits, and vegetables for the local market. All suburban areas had market gardens that produced vegetables, fruits, dairy and poultry for the cities (Ali, 1984, 1987; Khan and Haq, 1961). Farmers living in coastal districts always caught naturally grown shrimp from saline abandoned channels and sold them in the market. In the 1980s, with the greater globalization of trade, Bangladesh entered into the world market for vegetables, flowers, fruits and shrimp. Higher price incentive induced

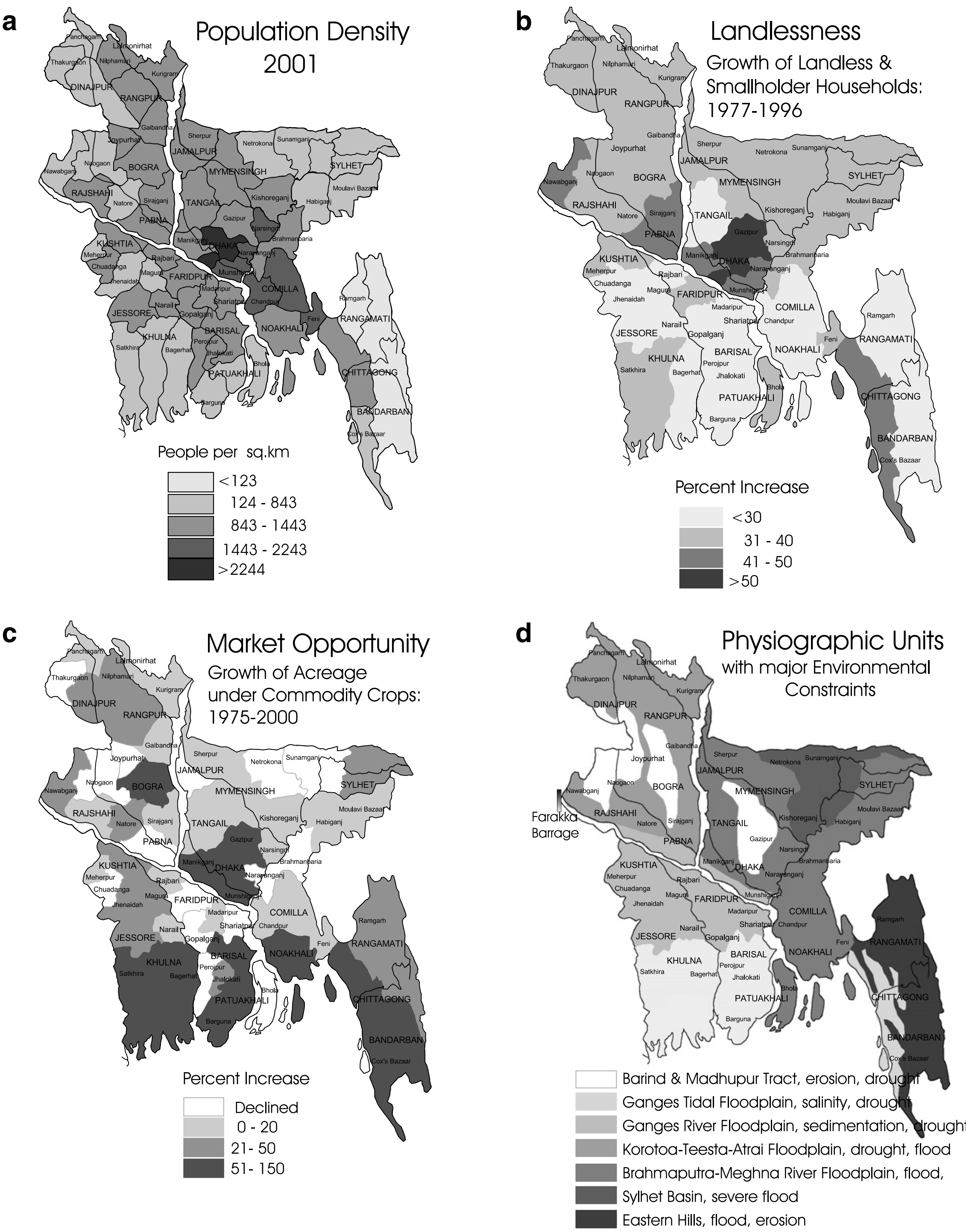

Fig. 2. Attributes of agricultural growth and rural system changes in Bangladesh.

farmers to transform both prime rice fields and marginal lands into market gardens and shrimp farms. As a result, large scale market gardens have flourished in Dhaka, Chittagong, Dinajpur, Rangpur, Bogra, Jessore and Kushtia; and shrimp ponds rapidly expanded in Khulna, Barisal, Patuakhali, Noakhali and Chittagong regions (Fig. 2c). Despite its higher economic returns, shrimp farming has caused serious environmental and soil quality degradation in coastal districts (Ali, 2004; Rahman, 1994).

3.5. Environmental constraints

Bangladesh is a flood prone country because of her location at the confluence of the Ganges, Brahmaputra and Meghna (hereafter GBM) Rivers in the Monsoon South Asia (Fig. 2d). Over the past 30 years, the rise of surface temperature (by 0.6 °C) in the region has caused abnormalities in its monsoon rainfall regime that caused 12 major floods and 11 droughts in Bangladesh and West Bengal

Table 1
Changing land holding size in Bangladesh: 1977–1996

Size of holding	% of rural households			% of land owned		
	1977	1983	1997	1977	1983	1997
Functional landless <0.2 ha	5.5	24.1	56.0	0.5	2.74	5.8
Smallholders 0.2–1 ha	44.3	46.3	30.7	18.3	26.2	32.2
Medium holders 1–3 ha	40.9	24.7	11.2	48.9	45.1	39.7
Large holders >3 ha	9.3	4.9	2.1	32.4	25.9	22.2

Source: BBS, The Bangladesh Census of Agriculture, 1983, p. 32 Table 5.
BBS, The Bangladesh Census of Agriculture, 1996, p. 74, Table 16.

province of India (Kripalani et al., 1996; Mirza, 2001; Mirza and Dixit, 1997; Pant and Kumar, 1997). In addition, various natural and human induced factors have increased the magnitude of flood, soil salinity and sedimentation of riverbeds that has hindered its agriculture and rural development.

As the single downstream country, Bangladesh drains some 115 million ha of surface runoff and 1.6 billion tons of sediment annually drawn from 1.75 million km^2 drainage basin, 93% of which lies in India, Nepal, Bhutan and China (Islam and Sado, 2000; Mirza, 2003). During July–October of each year, high rainfall (>2000 mm) in the GBM drainage basin and snowmelt water from the Himalayan Mountains increases the combined peak discharge of the Rivers up to 190,000 m^3 s^{-1} which exceeds their drainage capacity of 75,000 m^3 s^{-1}, and causes hazardous floods affecting 42–69% of land in Bangladesh (Islam and Sado, 2000; Mirza, 2003). In April-May, however, delay and lack of the Nor'wester rainfall cause drought in its west and southwestern districts (Brammer, 1999).

Within the country, unplanned urban expansion via land filling has increased the magnitude of flooding in the cities. Across the international border, catastrophic earthquakes of 1897 and 1950 in Bengal and Assam Provinces of India, faulted lithological structure, seismic activity and high torrential rain had caused extensive landslides and soil erosion in the Himalayan Mountains (Brammer, 1996; Ives and Messerli, 1989; Hofer, 1998; Rogers et al., 1989; Carson, 1985). In addition, massive deforestation and intensive cultivation throughout the GBM River basins and on the Himalayan hill slopes have accelerated the rate of soil erosion (Impat, 1979; Nakarmi et al., 2000; Carson, 1992; Gardner and Gerrard, 2003). Massive soil erosion has contributed high volume of sediment to the GBM drainage systems that has entered into Bangladesh and increased the rate of sedimentation of riverbeds vis-à-vis the risk and magnitude of flooding in the country.

In the mid-1970s, the Government of India had constructed the Farakka Barrage on the Ganges River and diverted its flow through the Bhagirati River in West Bengal in order to expand the dry season irrigated agriculture in the province; to ensure the supply high volume of consumable water to Calcutta city; and to keep the Calcutta port navigable round the year (Crow and Singh, 2000; Gaan, 1999). Since its inception in April of 1975, the Ganges River discharge in Bangladesh drastically dropped from $\geqslant$2000 m^3/s in April of 1973 to 502 m^3/s in April of 1996 although some of those years were abnormally wet (BWDB, 2000; Khan, 2001). Although India and Bangladesh signed the Ganges Water Treaty in December 1996, the river's discharge remained below 1000 m^3/s and promoted soil and water salinity, sedimentation, and ground water depletion in 4.3 million ha of its floodplains (Fig. 2d; Khan, 2001; Mirza, 1998).

3.6. Technological change in agriculture

In Bangladesh, the Green revolutionary technological change in agriculture was launched in the mid-1960s to achieve self-sufficiency in food production (Hossain, 1990). The new technology package included high yielding variety (HYV) rice seeds, NPK based chemical fertilizers, pesticides and low-lift irrigation pumps. During 1975–2000, the area of low-lift pump irrigation and HYV rice cultivation have increased three fold and the use of chemical fertilizers per ha has doubled.

3.7. Growing institutional support

Agricultural growth and rural development have always been the top priority in the Bangladesh Government's planning (Blair, 1985; Hye, 1989). The Government and NGOs have excavated irrigation canals, constructed roads and flood control embankments, and launched rural electrification, coastal afforestation, illiteracy eradication, and "health for all" projects to help agricultural and rural development. Large number of small capital loans provided by the Grameen Bank, BRAC and other NGOs to the rural poor has increased their off-farm employment opportunities (Lewis, 1993). Increased opportunities of employment for Bangladeshi workers in foreign countries and huge capital inflow also promoted socio-economic change in rural areas.

4. An induced rural system change model

An induced model of rural system change (RSC) is proposed and tested in this study. The model assumes that rural system changes in Bangladesh are outcomes of farmers' mixed production behavior which is induced by growing population and market demands; and that farmers' land use decision making behavior is modified by the mediating effects of prevailing political economic, environmental, institutional, technological conditions. The model examines three paths, each linking population and market demands to a rural system change index (RSCI) through specific mediating conditions (Fig. 3). Path 1 examines the direct effects of population and market demands on rural system changes under the existing political economy (small farm size). It assumes that population growth and market price incentives will induce farmers to increase their consumption and commodity production which will ensure food security, and increase farm income that will bring social development. Path II examines the effect of population and market demand on rural system changes under the existing political economy and environmental constraints. This path explores how the environmental constraints impede the power of population pressure, market force and political economic conditions. It assumes that despite adequate population and market demands and extreme land stress, farm production will not increase to an expected level in a constrained environment. Finally, Path III examines the effects of population and market demands on rural system changes under the existing political economy, environment, institutional and technological conditions. It assumes that severe environmental constraints would hinder the effect of demand; and technological change would be necessary to overcome those constraints in order to achieve agricultural growth and rural system changes. However, major technological change will not occur until the government and NGOs provide adequate institutional support to farmers by way of excavating irrigation canals, building flood control embankments, and distributing capital loans to purchase low-lift irrigation pumps and chemical fertilizers. Once the new technology is capable of reducing the environmental constraints, the demand forces will exert their full effects to induce farmers to change their land use and cropping patterns and increase the frequency of cultivation; land use/land cover changes and agricultural intensification will increase food and commodity production; and finally, increases in food security and farm income will improve rural socio-economic, health and living conditions. Thus, the model proposes a linkage between growing population and market demands and rural system changes. Such linkage, however, is modified by direct and indirect effects of various mediating forces. The study differs from Turner and Ali (1996) study on the grounds of data scale (household vs. district), measurement of market force, environmental constraint and technology variables, inclusion of two institutional variables,

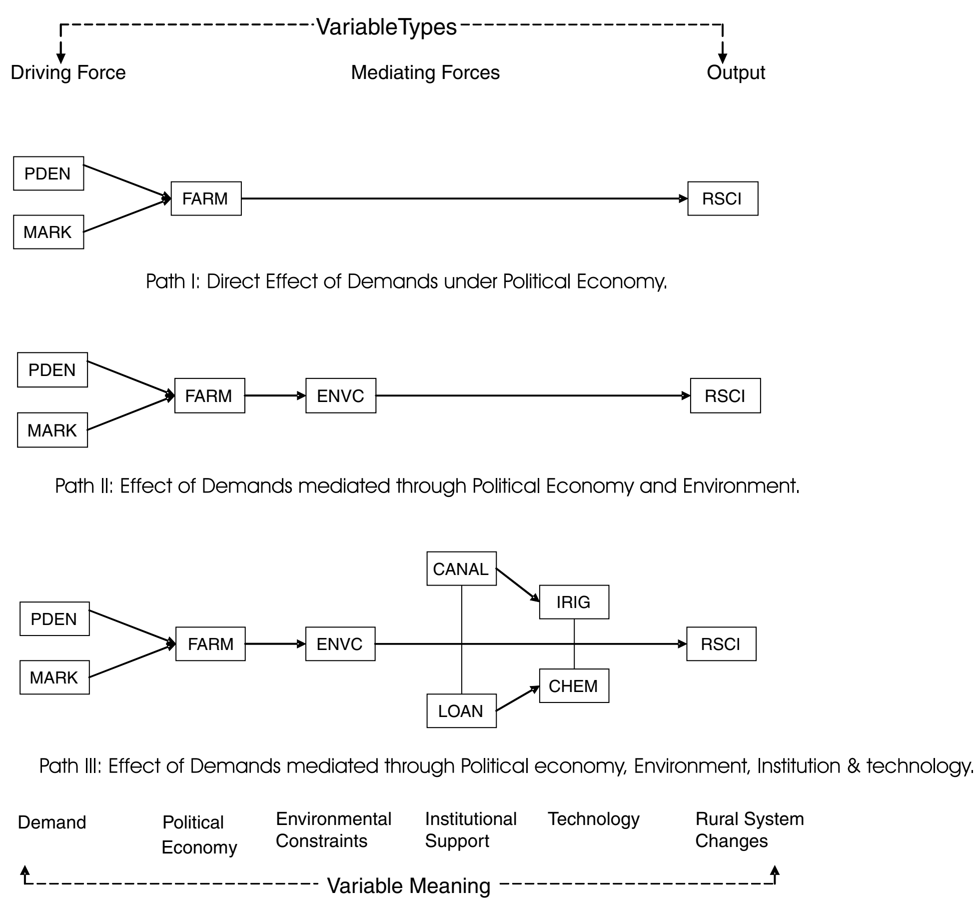

Fig. 3. Various paths leading to induced rural system changes.

and defining a new dependent (output) variable constructed as a hybrid by merging the indicators of land use, agriculture and socio-economic change. Turner and Ali (1996) study examined the role of inducing demands and other mediating forces on agricultural intensity and land productivity (two output or dependent variables). The present model will examine the role of demands and mediating variables on rural systems change index as a single dependent variable that represents temporal changes in land use, agricultural growth and socio-economic conditions in rural areas. To construct this single dependent variable, 18 key indicators of rural land use, agricultural and socio-economic changes will be statistically decomposed and merged (see Section 6).

5. Variables and data

The proposed model has specified eight independent variables and a dependent variable (Fig. 3, Path III; and Table 2). The independent variables include two inducing (driving force) variables representing population pressure and market demands, and six mediating variables representing political economy, environmental constraints, technology, and institutional support conditions. The magnitude of population growth and market demands are measured, respectively, by percent change in population density in a district during 1975 and 2000 (PDEN); and average market price index (base = 1975) of commodity crops (MARK). The political economic condition is expressed by percent change in the number of smallholder farmers in a district during the 1976 and 1996 agricultural census years (FARM). The environmental constraint level is measured in terms of vulnerability (the number of constraints multiplied by their frequency of occurrence in the past 25 years) of a district to flood, drought and salinity (ENVC). Most important aspect of technological change in Bangladesh is the expansion of HYV rice using chemical fertilizers and low-lift pump irrigation.[2] Two technology variables included in the model are percent change in area irrigated by low-lift pumps (IRIG), and percent change in per ha use of chemical fertilizers (CHEM). The acreage of HYV rice is highly correlated with the irrigated area; hence, it is not included in the model. The level of institutional support is expressed by percent change in the mileage of excavation of irrigation and flood control canals (CANAL), and percent change in the amount of capital loans distributed to farmers (LOAN). Finally, an index of rural system change (RSCI) is taken as the dependent variable in the model. This index is constructed by accounting the percent changes in 18 indicators best representing land use, agriculture, and socio-economic conditions (Table 2).

Table 2
Selected indicators of agricultural growth and rural system changes in Bangladesh

Land use/land cover change indicator
1. Percent change in area under settlement 1975–2000

Agricultural growth indicators
2. Percent change in cropping intensity 1975–2000
3. Percent change in land productivity, 1975–2000
4. Percent change in labor productivity, 1975–2000
5. Percent change in productivity of per ha irrigated land, 1975–2000
6. Percent change in productivity of per ton of chemical fertilizers, 1975–2000
7. Percent change in per capita farm income, 1975–2000

Rural social change indicators
8. Percent change in rural literacy, 1975–2000
9. Percent change in the number of schools per 100,000 people, 1975–2000
10. Percent change in paved roads in rural areas, 1975–2000
11. Percent change in the number of rural markets per 100,000 people, 1975–2000
12. Percent change in the number of rural health clinics per 100,000 people, 1975–2000
13. Percent change in the number of post offices per 100,000 people, 1975–2000
14. Percent change in the number of rural banks per 100,000 people, 1975–2000
15. Percent change in the number of public storage in rural markets, 1975–2000
16. Percent change in the number of rural brick-built houses, 1975–2000
17. Percent change in the number of rural households with electricity, 1975–2000
18. Percent change in the number of rural households with sanitary toilet and tube-well, 1975–2000

Independent variables
1. Percent change in population density (PDEN)
2. Market price index (base = 1975) of commodity crops (MARK)
3. Percent change in the number of smallholders and functional landless households (FARM)
4. Environmental constraint index (no. of times land affected by flood, drought and salinity) (LAND)
5. Percent change in area irrigated by low lift pumps (IRIG)
6. Percent change in per ha use of NPK chemical fertilizers (CHEM)
7. Percent change in mileage of excavation of flood control and irrigation canals (CANAL)
8. Percent change in the amount of capital loans distributed (LOAN)

Dependent variable
Index of rural system change (RSCI) based on 18 indicators specified above

Sources: A Bangladesh Bureau of Statistics, Statistical Yearbooks, 1975–2000.

The Bangladesh Bureau of Statistics (BBS), Meteorology Department (BMD), Water Development Board (BWDB), Soil Resource Development Institute (SRDI) and Ministry of Local Government and Rural Development (MLGRD) are reliable national sources for published data. These government organizations employ professional enumerators, scientists and technical experts to collect,

[2] Both chemical fertilizers and low-lift pumps are sold to farmers via dealership and extension services, however, data on the number of dealers are neither reliable nor available for all 64 districts; hence they are not included in the model.

process, preserve and report field survey and experimental data on large number of variables with acceptable degree (>95%) of accuracy (BBS, 1999, p. 20).[3]

Raw data for population density, market price index for commodity crops, number of small holder farms, irrigated area, distribution of chemical fertilizers, land use, acreage, yield, market price of 21 crops, and cropping intensity were collected for the years 1975 and 2000 from the (BBS 1975, 2000). The cropping intensity, acreage and yield of crops vary each year; hence, their five year (1970–1975, and 1995–2000) average data were taken into account. Changing area under settlement, which reflects its expansion through conversion of farmland and forest area, was taken as a measure of land use/land cover change. To construct the environmental constraint variable, data on frequency of occurrence and area affected by flood, drought, and soil salinity during 1975–2000 were collected from the BMD, BWDB and SRDI. To construct two institutional support variables, data on canal excavation and construction of flood control embankment were collected from the MLGRD; and that on capital loans were collected from the Bangladesh Krishi Bank and the Grameen Bank. Percentage change (base = 1975) in each raw data were calculated to compute eight independent variables and 18 indicators defined in Table 2.

Most studies in the cultural ecology tradition analyze sample household data collected through field research in small communities. The present study departs from that tradition and analyzes the census data for 64 districts of Bangladesh. Although changes in data scale and level of analysis often affect the results (see Keys and McConnell, 2005), use of district level data, instead of household data, would not distort the results of this study because the census data used here were actually collected through sampling and household enumeration.

6. Methods

6.1. Measures of agricultural growth

Several studies have measured agricultural productivity as an average output of land, labor and technology inputs; and agricultural growth as increases in cropping intensity and agricultural productivity (Dayal, 1984; Turner and Doolittle, 1978). In this study, agricultural growth is measured as an average of percent change in cropping intensity, land, labor, technological productivity and per capita farm income derived from 21 field crops and fisheries during 1975–2000. The cropping intensity (%) of a district was computed by dividing the total cropped area (TCA) by the net cropped area (NCA) and multiplying the result by 100. The total cropped area (TCA) accounted for all fields under annual, double and triple cropping and was computed in the following manner:

$$\begin{aligned} \text{TCA} = {} & (\text{Area annually cropped}) \\ & + (\text{Area double cropped} \times 2) \\ & + (\text{Area triple cropped} \times 3) \end{aligned} \tag{1}$$

For each census year, the value of each crop was calculated by multiplying its area by yield and constant wholesale price (base year = 1975); the total value added by agriculture (TVA) was obtained by adding the values of 21 field crops and fisheries. The cost of inputs was not included in computing productivity because of lack of data. Land productivity (ha^{-1}) was calculated by dividing the TVA by the NCA. Labor productivity was computed by dividing the TVA by the total agricultural labor force. Technological productivity of irrigation and chemical fertilizers were calculated, respectively, by dividing the value of HYV boro rice by the irrigated area; and by the kg of chemical fertilizers used. Per capita farm income was computed by dividing the TVA by the district's total population.

6.2. Computation of the index of rural systems change

Three separate indices were computed to examine the status of land use change, agricultural growth, rural social change, and an overall rural systems change (RSCI). This involved statistical decomposition of 18 indicators by using a *varimax* rotated factor analysis which yielded five factors (Table 3).[4] Factor 1 with high positive loadings on rural markets, storage, roads, banks and post offices highlighted growing economic opportunities in rural areas. High loadings on Factor 2 and 4 indicated significant change in land use, cropping intensity, land, labor and technological productivities. Factor 3 highlighted social changes indicated by high positive loadings on rate of literacy, number of schools and rural health centers. Factor 5 highlighted

[3] The BBS follows the international practice of trade-offs to collect basic population characteristics through national census; and verifies their quality through post-enumeration checks. The Bureau collected detailed agricultural and socio-economic data employing the "Stratified Two Stage Cluster" sampling design that covered 3.81% of 211,638 enumeration areas and 0.84% of all households in the country (BBS, 1999, p. x, 8). The BMD maintains 48 daily weather stations throughout the country and publishes climatic data annually. The BWDB also maintains 55 hydrology stations to record and publish rainfall and flood level data. The SRDI has several field units and a central research laboratory in Dhaka that collects and publishes data on soil quality, floodibility and drought effectiveness for all soil series in Bangladesh.

[4] Factor analysis technique is known for grouping large number variables into few new variables or factors that clearly represent the original set of variables (Shaw and Wheeler, 1989). The grouping is done by geometric rotation of variables (based on bi-variate correlation coefficient) about their origin to single out the most significant cluster of variables. Geometrically, both oblique and orthogonal rotations are used; however, the latter is most commonly used by geographers because it assumes that the derived factors are unrelated, and that each variable in group has a factor loading of ±1.0 on one factor and 0.0 on other factors. Among three orthogonal rotations, quartimax rotation simplifies the rows of a factor matrix; varimax simplifies its columns; and equamax simplifies both rows and columns. Comparatively, the varimax rotation, maximizes the sum of variance of the square loadings in each column and hence most popularly used by geographers.

Table 3
Factor analysis of 18 indicators of agricultural growth, rural living, economic and social changes

Factors	Highest factor loadings and variable definition	Cumulative % of variance	Eigenvalue
Factor I (economic)	0.89% change in the number of rural markets 0.86% change in the number of post offices 0.74% change in the number of storage 0.56% change in the number of banks 0.55% change in mileage of paved roads	17.38	3.13
Factor II (land use change and agricultural growth)	0.92% change in area under settlement 0.90% change in cropping intensity 0.77% change in land productivity 0.74% change in irrigation productivity	33.72	2.94
Factor III (social)	0.90% change in the number of hospitals 0.83% change in the number of schools 0.82% change in the number of rural literacy	48.14	2.59
Factor IV (agricultural productivity)	0.92% change in labor productivity 0.87% change in per capita farm income 0.68% change in fertilizer productivity	62.37	2.56
Factor V (living condition)	0.85% change in houses toilets and tube wells 0.80% change in brick-built houses 0.73% change in houses with electricity	74.07	2.11

changes in rural residential living conditions with high loadings on housing structure, availability of electricity, sanitary toilets and purified drinking water supply.

Factor scores of each factor were ranked into five quintiles as follows: scores >1.5 (5), 1.5–0.5 (4), 0.5 to −0.5 (3), −0.5 to −1.5 (2), and <−1.5 (1). High rank scores would indicate high degree of land use change, agricultural growth and social development. Rank scores of Factor 2 and 4 were added to construct the land use change and agricultural growth index; those of Factors 1, 3, and 5 were added to compute rural social change index; and rank scores of all five factors were added to construct the rural systems change index (RSCI) which places each district on an overall scale of rural land use, agricultural, economic and social changes (see Tata and Schultz, 1988).

6.3. Testing the induced model of rural system changes

The induced model is formulated in terms of three paths each examining the effects of selected independent variables on the dependent variable, the index of rural system changes (RSCI). For each path, a separate multiple regression analysis was employed to assess the relative impacts of independent variables on the dependent variable. This is a multivariate causal model in which some independent variables directly influence the dependent variable while others only indirectly influence it. A path analysis was used to assess the direct, indirect, and total effects of independent variables on the index of rural system change. The direct effect of an independent variable was measured by computing the path coefficient (p_{ij}) or the standardized regression coefficient $\beta_{j\cdot k}$; where

$$\beta Y_{j\cdot k} = \delta_j/\delta_y * b_{Yj\cdot k} \quad \text{(see Wright, 1960)}. \tag{2}$$

The indirect effect of an independent variable X_{I} on index of rural system change (Y_{I}) via another independent variable X_j was calculated as

$$r_{ij}p_{Y\cdot j} \tag{3}$$

i.e., the product of correlation of X_{I} and X_j and the path coefficient between Y_{I} and X_j.

The total effect of each path consisting of several independent variables on the dependent variable was calculated as

$$r_{ij} = p_{ij} + \sum_{j=1}^{k} r_{ij}p_{ij} \tag{4}$$

i.e., sum of the direct effect via the path coefficient from an independent variable to the dependent variable and its indirect effects through other independent variables.

7. Results

7.1. The nature of rural system changes

7.1.1. Land use/land cover change and agricultural growth

During 1975–2000, as the national population of Bangladesh grew >80% and the number of municipalities increased from 74 to 223, significant land use/land cover change occurred throughout the country. Both net cropped and forest areas declined, respectively, by 15% and 60% as they were converted into urban and rural settlements which expanded by 25% (BBS, 1975, 2001). Rapid conversion of farmland and forestry into urban uses was most prominent in and around Dhaka, Chittagong, Khulna cities and Chittagong Hill Tract district.

Over the period in question, the national average cropping intensity increased from 145% to 206% due to expansion of dry season cultivation with the help of low-lift pump irrigation. Frequent cultivation of HYV rice, vegetables and shrimps increased both total agricultural output and land productivity; the latter increased from Taka 3116 in 1975 to Taka 6890 ha^{-1} in 2000 at a constant price. Labor productivity, however, declined from Taka 2635 to Taka 2306 per worker due to increase in surplus rural labor force who remained in farming due to lack of off-farm work. Technological productivities of irrigation and chemical fertilizer inputs declined by 40% under frequent occurrence of flood and drought, and increased soil salinity that reduced the efficiencies of those inputs. Per capita farm income increased by 29% indicating agricultural growth.

Accounting for land use and agricultural changes, the land use and agricultural growth index shows that 40 central and southwestern districts experienced moderate to high (scores 6–9) agricultural growth; and remaining 24 districts in the south, east, and northeast experienced low agricultural growth (scores 4–5). Frequent cultivation of irrigated rice, vegetable and shrimp was the key to high

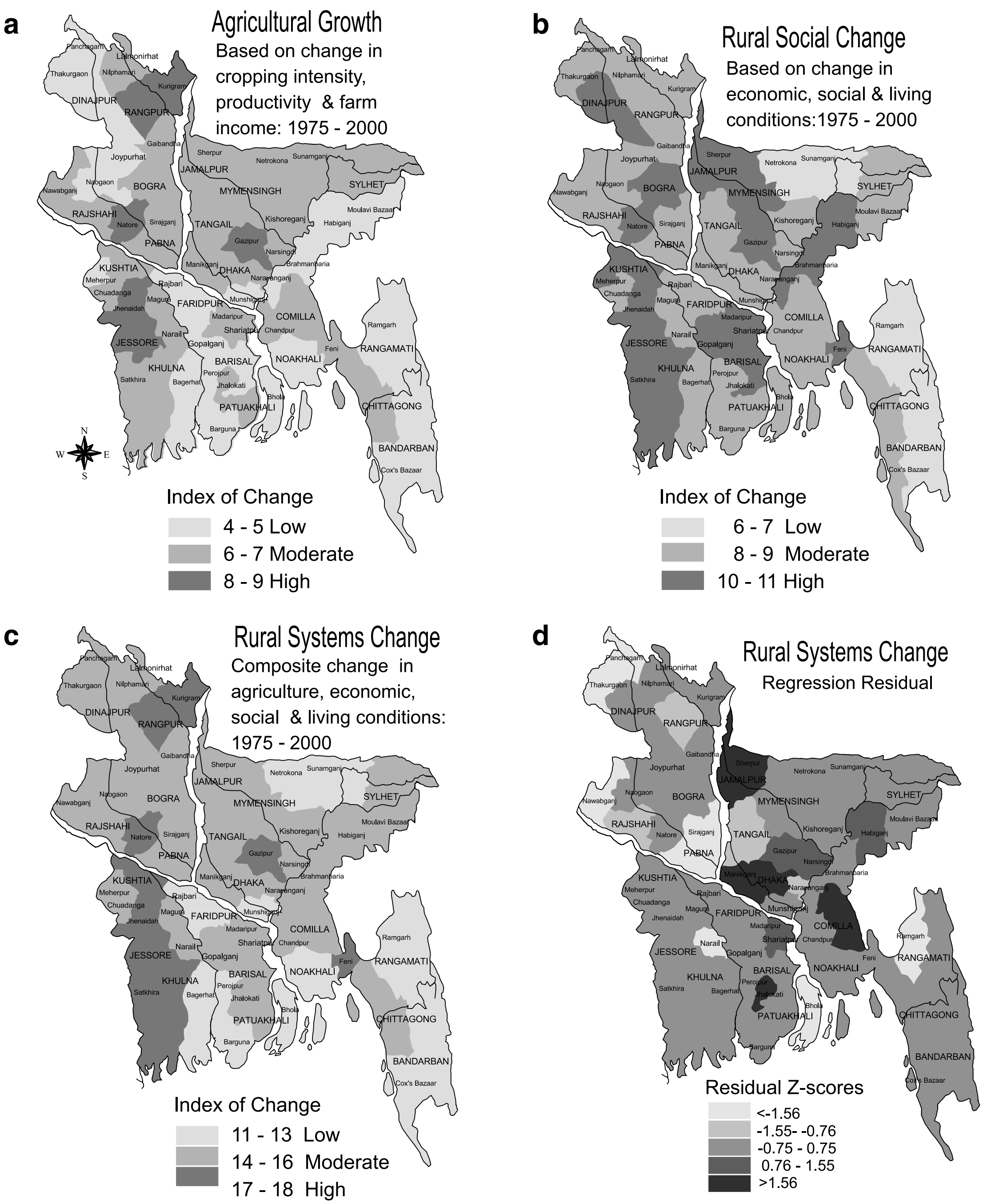

Fig. 4. Agricultural growth, social and rural system changes in Bangladesh, 1975–2000.

agricultural growth whereas severe dryness, monsoon flood, and soil salinity were responsible for agricultural stagnation (Fig. 4a).

7.1.2. Rural social changes

Rural areas in Bangladesh have experienced noticeable improvements in living conditions. The number of brick-built houses with electricity, sanitary toilets and drinking water tube wells has increased by 173%. Increased farm income, off-farm income by seasonal migrants working in urban areas, and cash remittance by Bangladeshi labors working overseas allowed many rural residents to change their living conditions. However, the opportunities of off-farm and overseas employment are still negligible compared to growing rural unemployment in the country.

Rural economic and social conditions have changed due to rapid growth in commodity production which has fostered the establishment of new rural markets, banks and storage facilities, and construction of paved roads to connect rural areas with urban markets. During 1975–2000, the number of rural markets has increased by 84%; banks and public storage by 30%; and the mileage of paved roads increased by 63%. Rural literacy has increased by 49% due to the establishment of new schools and colleges. Rural public health services have improved due to expansion of paved roads, telecommunications and government and NGO sponsored health extension services. Accounting for changes in housing, economic and social conditions, the social change index indicates high degree of socio-economic development (scores 10–11) in Khulna, Jessore, Satkhira, Kushtia, Dinajpur, Jamalpur, Faridpur, Mymensigh, Feni and Brahmanbaria; and low development (scores 6–7) in severely constrained Sunamganj, Rangamati, Ramgarh and Bandarban; and moderate (scores 8–9) development in the remaining 42 central, western and southeastern districts (Fig. 4b).

7.1.3. Rural system changes

Combining the land use change, agricultural and socio-economic developments, the rural systems change index has placed Jessore, Khulna, Kushtia, Natore, Rangpur Kurigram, Gazipur and Feni in high; Sunamganj, Netrokona, Rangamati, Bandarban, Faridpur, Rajbari, Noakhali, Bagerhat, Barguna, and Bhola in a low category; and rest of the country in moderate category of rural system changes (Fig. 4c). Access to urban market, success in frequent cultivation of HYV rice, vegetables and shrimp have been responsible for moderate to high degree of rural system changes.

7.2. Modeling induced rural systems change

7.2.1. Path I: Effect of demands on rural system changes

Path I examined the effects of population and market demands on rural system changes. Bangladeshi farmers operate small farms to produce consumption and commodity crops; hence, the effects of demand are actually mediated through the operational farm size. Multiple regression of the index of rural systems change (RSCI) against population density, market price index, and the number of smallholder farms has explained 71% of the total variation of rural system changes (Table 4). As for the direct effects (standardized regression coefficients or β-value), increase in population density has emerged as the most powerful ($\beta = 0.58$) factor inducing rural system changes, and it was followed by market price index ($\beta = 0.33$), and farm size ($\beta = -0.24$) variables. It was observed that the direct effects of two demand variables were profoundly positive, however, when mediated through the farm size, which had negative impacts on both dependent and independent variables, the total effect of both demands were lessened as indicated by the path coefficients (Table 4; col. 6). This finding suggests that both population pressure and market incentives have contributed to rural system changes by inducing land use changes, agricultural growth and social change; however, growing landlessness hindered this process.

7.2.2. Path II: Effect of environment on rural system change

Path II examined the effect of environmental constraints on rural system changes. The second multiple regression of rural system change index (RSCI) against population density, market price index, farm size, and environmental constraint has explained 78% of the total variation of rural system change. Both population density and market price index showed positive effects while both farm size and environmental constraints showed negative impacts on rural system change. As for their direct effects, population density emerged as the strongest positive ($\beta = 0.40$) determinant while environmental constraint appeared to be the strongest negative ($\beta = -0.37$) factor influencing rural system change. Interestingly, the path analysis results showed that when mediated through farm size and environmental constraint variables, the direct effects of both demand variables were drastically reduced (Table 4; col. 6). This finding indicates that despite high population pressure and market price incentives, rural systems will not change to an expected level if the environment is not favorable and landlessness continues to grow. Severe environmental constraints such as flood, drought, and soil salinity significantly impeded agricultural growth regardless whether it is for consumption or commodity production. Environmental constraints reduce agricultural production, force farmers to sell their land in order to meet consumption and social needs, and thus cause further landlessness that hinders rural systems change. This relationship was evidenced by increased total effect of farm size via environmental constraints (Table 4; col. 6).

7.2.3. Path III: An induced model of rural system change

Path III examined the full driving power of demand variables on rural system changes as it mediated through political economy, environment, institutional and technological conditions. The final multiple regression of rural

Table 4
Adjusted coefficient of determination (R^2), direct, indirect and total effects of eight independent variables on the index of rural system changes in Bangladesh: multiple regressions and path analysis results

Induced path	Dependent variable	Independent variables in the model	Multiple regression results	Path analysis results	
			Direct effects of driving forces indicated by standardized regression coefficient (β)	Indirect effects via mediating variables, $r_{ij}p_{Y \cdot j}$	Total effects of driving force, r_{ij}
Path I: Effect of demand mediated via political economy	Rural system changes index (RSCI)	% Increase in population density (PDEN)	0.58	−0.14 (FARM)	0.44
		% Change in market price index (MARK)	0.33	−0.07 (FARM)	0.26
Adjusted R^2 change = 0.71		% of smallholder households (FARM)	−0.24		
Path II: Effect of demand mediated via political economy and environmental constraints	Rural systems changes index (RSCI)	% Increase in population density (PDEN)	0.40	−0.09 (FARM) + −0.26 (ENVC)	0.05
		% Change in market price index (MARK)	0.24	−0.05 (FARM) + −0.11 (ENVC)	0.08
		% of smallholder households (FARM)	−0.15	−0.06 (ENVC)	−0.21
Adjusted R^2 change = 0.78		Environmental constraint index (ENVC)	−0.37		
Path III: Effect of demand mediated via political economy, environment, institutional support, and technological changes	Rural systems changes index (RSCI)	% Increase in population density (PDEN)	0.23	−0.05 (FARM) + −014 (ENVC) + 0.10 (CANAL) + 0.12 (LOAN) + 0.03 (IRIG) + 0.09 (CHEM)	0.38
		% Change in market price index (MARK)	0.18	−0.04 (FARM) + −0.09 (ENVC) + 0.05 (CANAL) + 0.08 (LOAN) + 0.04 (IRIG) + 0.02 (CHEM)	0.24
Adjusted R^2 change = 0.91		% of smallholder households (FARM)	−0.14		
		Environmental constraint index (ENVC)	−0.22		
		% Increase canal excavation (CANAL)	0.16		
		% Increase in capital loans (LOAN)	0.21		
		% Increase in area under low-lift irrigation (IRIG)	0.15		
		% Increase in use of chemical fertilizers (CHEM)	0.15		

systems change index (RSCI) against population density, market price index, farm size, environmental constraints, excavation of canals, distribution of capital loans, area irrigated, and use of chemical fertilizer variables has explained 91% of the total variation of rural systems change (Table 4). Among the demand variables, population density has emerged as the most important predictor ($\beta = 0.23$) positively influencing rural system change, and was followed by the market price index ($\beta = 0.18$). Agriculture will not grow if both consumption and commodity demands do not grow adequately to induce farmers to intensify cultivation practices; and rural social change will not occur until food security is achieved and farm income increases to raise people's aspiration level. Farm size was inversely related to rural system change indicating that growing landlessness retarded the process of rural system change.

The environmental constraints index emerged as the strongest negative predictor that hindered rural system change ($\beta = -0.22$). Both agricultural intensification and rural development processes are inhibited by adverse impacts of environmental constraints. The longer the district land is affected by flood, drought and salinity, the shorter would be its cultivation regime, the lower be its productivity level, and the slower be its rural development actions.

Two institutional support variables such as canal excavation and capital loan distribution exerted significant positive influence on rural system changes (Table 4). In Bangladesh, during the mid-1970s and early 1980s, the government and NGOs excavated canals and re-excavated smaller silted channels in drought prone southwestern and northwestern districts to trap flood and rainwater that helped dry season cultivation of irrigated HYV rice and cash crops. However, the excavation of silted GBM Rivers was not possible due to lack of resource and technology, and therefore, devastation of crops and property by major floods in the central and northeastern districts could not be avoided. Distribution of capital loans by the government and NGOs allowed farmers to buy irrigation pumps, chemical fertilizers and seeds that helped multiple cultivation of HYV rice.

Technology variables such as increased area under irrigation, and uses of chemical fertilizers and pesticides have exerted positive effects on rural system changes. While the success in wet season cultivation of HYV rice and commodity crops depended on flood control, their dry season cultivations and higher yields were fully dependent on the expansion of low-lift pump irrigation and efficient uses of chemical fertilizers and pesticides. Expansion of HYV rice and commodity crops had generated higher farm income that facilitated social changes.

While the standardized regression coefficients have demonstrated the direct individual effect of each independent variable on rural system change, the path analysis results have revealed their indirect and total effects and thus provided some very important insights about the precise role played by the driving forces in conjunction with the mediating variables to cause rural system change. It appears that population pressure and growing market price incentives were most essential factors inducing agricultural growth and rural development. However, their inducing effects were drastically reduced by growing landlessness and severe environmental constraints (Table 4, path II col. 5 and 6). While the negative effects of growing landlessness could not be controlled in the face of continuous population growth, the adverse effects of environmental constraints were to some extent reduced by technological change. However, major technological changes waited until institutional support from the government and NGOs became widely available to farmers. Technological change exerted its full force to reduce environmental constraints and allowed intensive cultivation of food and commodity crops; and both total food production and farm income increased simultaneously in response to growing population and market demands. Although the effects of both demand-based driving forces initially declined due to inverse mediating effects of farm size and environmental constraints, their individual total effects have substantially increased (from $\beta = 0.23$ to $r_{ij} = 0.38$ for PDEN; and $\beta = 0.18$ to $r_{ij} = 0.24$ for MARK) when the mediating positive effects of canal excavation and loan distribution allowed technological changes that reduced environmental constraints (Table 4, Path III, col. 6).

Accounting for 91% of its causes, the model provided a clear understanding of induced rural system changes in Bangladesh. The map of multiple regression residuals on rural system change index (RSCI) shows that very low standardized residual scores ($z = -0.75$–0.75) occurred in 54 districts (Fig. 4d). This indicates high level of predictability of the model that well demonstrated the process of induced rural system change. Several high positive residual scores (>0.76) found in Jamalpur, Dhaka, Manikganj and Comilla districts, however, indicate that additional factor, such as rapid development of highways connecting these districts with Savar, Gazipur, Demra and Kaliakoir industrial corridors of Dhaka City, may have accelerated land use, agricultural and socio-economic changes in those districts. Similarly, high negative scores (<−0.76) found in Narail, Pabna, Sirajganj, Thakurgaon, Rangamati, and Chapai Nawabganj may indicate that low population density, lack of market opportunities and institutional supports may have stymied their rural system changes.

8. Discussion

8.1. Theoretical and policy implications

The present study has several important theoretical implications toward the induced intensification studies. First, its results supported the basic argument of the induced intensification thesis that population growth and market incentives induce agricultural growth (cropping intensity and land productivity increases) as contended by Turner and Ali (1996). Second, the model has expanded the scope of the induced intensification thesis by examining the role of growing population and market demands on rural system changes which include rural land use/land cover changes, and socio-economic development in addition to agricultural growth (cropping intensity, land, labor and technological productivity, per capita income increases). This expansion was achieved through statistical decomposition and merger of key indicators of land use, agricultural and socio-economic changes into a single dependent (output) variable. The present model, therefore, has much broader and better applicability for understanding the current status and formulating future rural development strategies. Third, the model modified the earlier induced intensification model (that included environmental constraints, technology and political economy) by incorporating two institutional support variables as mediating forces. In recent decades, institutional forces such as small capital loan among others have exerted strong positive influence on rural land use/land cover changes, as well as agricultural and socio-economic development in Third World countries (see Boyce, 1987; Yunus, 2000). However, the role of institutional forces was not adequately tested in earlier induced intensification studies (e.g., Turner and Ali, 1996). Therefore, incorporation of two institutional variables has enhanced the utility of the induced model toward rural development. Fourth, the present model has substantially refined the earlier model by using a precisely defined market price index as a direct measure of market demand instead of its surrogate measure (e.g., percent of farmland under commodity production) used earlier (Turner and Ali, 1996). Yet another major implication of this study lies with its analysis of macro-scale (district) census data replacing micro-scale (household) data collected from small rural communities as used in earlier induced intensification studies. While household data reflect smallholder behavioral issues and land use decisions and though they identify the obstacles of household socio-economic development, macro-scale data represent the spatial pattern resulting from individual production behaviors and indentify the obstacles to national and regional rural development. Most cultural and political ecological studies dealing with induced intensification and agricultural change report substantial changes in results if the scale of data analysis changes from micro to macro level (e.g., Keys and McConnell, 2005). Interestingly, in this study, results of macro-scale data analysis parallel the results of micro-scale analysis (Turner and Ali, 1996; Laney, 2002). Such parallelism broadens the utility of the present model toward national and regional rural development planning in Bangladesh and other Third World countries.

This study has also identified several issues of agricultural growth and rural development in Bangladesh that have important policy implications. First, the model suggests that population growth is the most powerful driving force inducing agricultural growth and rural system changes. It is to be noted here that under extreme population pressure and severe environmental constraints, Bangladesh agriculture had once stagnated in the 1970s (Ahmad, 1985; Ali, 1987). However, further population growth during 1975–2000 induced farmers to intensify agriculture via technological change which included multiple cultivation of HYV rice using chemical fertilizers, irrigation water, and changing techno-managerial strategies, which reduced the environmental constraints to agriculture. This human induced intensification has doubled the total food production, ensured food security, and increased the farm income that triggered rural social change. This path of induced intensification provides strong support to Boserup's theory of agricultural change (Boserup, 1965).

Second, increased market price for commodity crops has also exerted a strong positive effect on agricultural growth and rural system changes. Over the period in question, Bangladeshi farmers have responded to high world market price and demand for cultured shrimp, vegetables and fresh fruits; and cultivated them more frequently by transforming marginal lands and rice fields. Increased commodity production has increased farm income and allowed farmers to improve their socio-economic conditions. Notable positive impacts of commodity production on rural system change can be seen in shrimp producing Satkhira, Khulna and Bagerhat districts where remarkable development in road transport communication and socio-economic conditions are visible. This finding provides strong support to Schultz's commodity demand thesis of agricultural change (Schultz, 1964).

Third, the study results strongly show that growing landlessness has negatively influenced the rural systems change. This finding provokes two interesting debates on causes of landlessness and its role in farming efficiency. Regarding the issue of growing landlessness, the existing literature highlights that various demographic, environmental, social and political economic conditions contribute to landlessness in Bangladesh (Khan, 2004). Population growth and effectiveness of the law of inheritance cause the rapid decline of per capita land and farm holding size. Environmental constraints such as river bank erosion also lead to landlessness. Situations such as crop failure (due to flood, drought, and soil salinity), and urgent social needs (in case of children's marriage, education, and cost of overseas migration) force farmers to sell their land. On the debate of efficiency, several studies analyzing district level aggregate census data reported an inverse relationship between farm size and agricultural productivity in Bangladesh (Boyce, 1987; Griffin et al., 2002; World Bank, 2000). In contrast, analysis of household data across both developed and undeveloped villages shows little or no difference between large and small farms in terms of productivity (Mahbub Ullah, 1996, pp. 235–237). Regardless of efficiency, the benefit of nationwide agricultural growth and rural social change has been biased toward large holders; and landless and smallholders suffered from growing unemployment and remained vulnerable to poverty and famine as observed during the last two decades in Kurigram districts in northern Bangladesh (Daily News, 2005; Ali, 2006). The most important obstacle for uniform agricultural growth and rural systems change is the uneven distribution of land resources, and disproportionate access to capital and other institutional support (Boyce, 1987). Frequent land reform is necessary to achieve uniform rural development. Both tenurial and redistributive land reforms had been implemented in Bangladesh to remove this obstacle and redistribute land to landless farmers; however, the former has created fewer owners and a large number of owner-cum-tenant and tenant farmers while the latter failed due to inherent loopholes in the reform administration (Byres, 2004; Mahbub Ullah, 1996; Griffin et al., 2002; Jannuzi and Peach, 1980; Khan, 2004). Agricultural economists dealing with agrarian reform even have doubts on the success of equal distribution of farmland among farmers of all categories in increasing land and labor productivity, which they believe will only create large number of small farmers (Khan, 2004; Mahbub Ullah, 1996). To transform land and labor productivity among all farmers, they would suggest radical agrarian transformation via changing the distribution of political powers that would strongly implement the reformation; land consolidation to create farms with higher productivity and ability to generate and re-invest an agrarian surplus; and administrative and institutional reformation to improve land administration system that will remove corruption in protecting land rights of all farmers (Khan, 2004; Mahbub Ullah, 1996; Rahman, 1996a,b; Toufique, 2001).

Fourth, the study shows that technology such as the uses of chemical fertilizers and irrigation has positively contributed to agricultural growth and rural systems changes. However, the declining productivity of these inputs owing to severe environmental constraints was also noticeable. In order to reduce the negative impacts of environmental constraints on agriculture, large scale excavation of major rivers and construction of flood control embankments and water reservoirs should be continued to trap and regulate flood water and use them for dry season cultivation. This can increase the productivity of technology inputs.

Fifth, the land use/land cover change data used in this study showed rapid decline of farmland and forestry and high percent increase in cropping intensity which otherwise indicated loss and over-cultivation of farmland in response to growing population and market demands. Such loss of farmland and over-cultivation may hinder future rural system changes. To avert this situation, at least three policy measures should be taken into immediate consideration. First, careful urban land use planning and zoning is needed to reduce farmland conversion. Second, further technological change in the direction of genetic improvement of HYV rice crops, which would require less chemical fertilizer and thrive well in severely constrained environments, should be adopted to conserve and replenish soil fertility and sustain higher land productivity. This would gradually reduce the incidence of over-cultivation. Finally, population dependence on farming should be minimized by creating more rural off-farm and non-farm employment opportunities which would facilitate economic and social development. It is to be noted here that several NGOs like the Grameen Bank,[5] BRAC, ASA among others have been remarkably successful in creating off-farm employment opportunities in rural Bangladesh. Also, a limited (compared to need) number of rural youths with some education and skills have found overseas employment opportunities in the Middle East, Southeast and East Asian, European and North American countries. Their remittance of foreign revenues has contributed to rural development in Bangladesh. However, the precise role of off-farm employment and income on rural system changes has yet to be examined adequately.

9. Conclusion

This study has examined the conditions of agricultural growth and rural development in Bangladesh over the past 25 years. Aggregate district level data suggest that both cropping intensity and land productivity have increased over time in response to population growth and market forces; however, the intensification process has been hindered by severe environmental and social constraints. Institutional support from the government and NGOs has facilitated major technological change which reduced those constraints to cause agricultural growth and rural system change. Over the period in question, total food and commodity production, farm income and land productivity have increased; in contrast, both labor and technological productivities have declined, respectively, due to a substantial increase in total agricultural labor force, and declining efficiency of chemical fertilizers and irrigation under severe flooding and drought. Agricultural growth and increased farm income fostered rural development but at a slower pace owing to environmental and social constraints.

The study results demonstrate that both population pressure and market incentives have been the key driving forces inducing agricultural intensification and rural system changes. However, the driving powers of these forces are meditated through environment, technology and institutional factors. While population growth and market forces are paramount to rural system changes, adoption of more sustainable farming practices and genetically improved high yielding crops, continuous soil quality monitoring, urban land use planning and zoning, controlling market prices of both consumption and commodity crops are necessary so that increased farm production and high economic return can save farmlands from loss and over-cultivation under increased demands. Opportunities for rural off-farm work should be increased to reduce the reliance of rural populace on farmland and unemployment, and to protect farmers from vagaries of landlessness. Administrative land reform should be frequently executed with greater emphasis on improved implementation process. Flood control and irrigation projects should be expanded

[5] The Grameen Bank and its founder Professor Yunus shared the 2006 Nobel Peace prize for their success in alleviating rural poverty in Bangladesh.

to reduce the risk of environmental constraints to agriculture. Human induced intensification of cultivation in a technologically controlled environment would accelerate both agricultural growth and rural development.

The proposed induced model has adequately portrayed both the theoretical and real-world mechanism under which Bangladesh agriculture grew and rural systems changed over time. Its high predictability and explanatory power and expanded capability certainly has increased its wider utility in national agricultural and rural development planning in Bangladesh and other Third World densely populated and environmentally constrained nations in the tropics. However, there must be an enormous amount of additional research undertaken before one can make this claim.

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