The Impact of Cultivation and Afforestation in India
– A CGE Modeling Approach –

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Abstract
In India, because of its large population, there has been growing demand for lands that are used in primary industries, such as arable land, grazing land and forestry land. And a considerable amount of cultivation and afforestation has taken place in response to such demand. This study deals with these three types of lands and analyzes the economic impact in India of cultivation and afforestation, using a Computable General Equilibrium (CGE) model. The model explicitly addresses substitution between traditional goods (fuelwood, cattle dung, and draft animals) and modern goods (fossil fuel, chemical fertilizer, and capital such as agro machinery). The results show that the two types of land use change (cultivation and afforestation) have many contrasting effects on various indices.
Keywords: CGE model; India; Land Use Policy; Biomass Energy

1. Introduction
Due to population pressures, in India demand has been increasing for lands that are used in primary industries. This includes arable land, grazing land and forestry land. In response to this situation, many cultivation and afforestation projects have been conducted. In the 1950s and 1960s, numerous cultivation initiatives were actively carried out and approx. 700,000 hectares per year were cultivated. However, because India has achieved food self-sufficiency and since scarce land remains to cultivate, in recent years very little cultivation has taken place. Instead, many irrigation projects have been conducted and the focal emphasis of the nation's arable land policy has shifted from quantitative expansion to qualitative enhancement.

Meanwhile, afforestation programs represent quantitative-based land utilization policy that has been implemented in recent years, and it has taken place in large scale. The National Forest Policy hammered out in 1988 places emphasis on afforestation programs for degraded forests, barren lands and public land with the aim of boosting production of fuelwood and fodder. The policy goal is to increase the country's area under tree cover from 20% to 33%, and to achieve this goal, an additional area of approx. 33 million ha needs to be afforested and about 31 million ha of damaged forestland needs to be reforested (FAO, 1997). During the first half of the '90s, about one million hectares was afforested per year in India (FAO, 1997).

When studying the impact of land use changes, comprehensive analysis is essential because such changes not only affect sectors where there are land fluctuations, but also other sectors as well via inter-industry ramifications. Therefore this study considers three types of land, i.e. arable land, forestry land, and grazing land, and analyzes the economic impact of land use change using a CGE (Computable General Equilibrium) model.

There are several CGE models which address conditions in India such as Narayana et al (1991), Alber et al (1994), Parikh et al (1997), Rajesh et al (1998), and Storm (1993). However, most of these analyze trade policy or tax policy. Only Alber et al (1994) analyzes land use change although it is difficult to see the impact in detail since they cover only two sectors (agriculture and non-agriculture). In addition, it is difficult to analyze afforestation programs because the above-mentioned models do not cover forestry or grazing land. Alber et al conducted a simulation of land-augmenting technical changes (such as irrigation) by increasing the amount of agricultural land since increasing the productivity has the same effect as increasing the quantity of arable land. Based on this assumption, the results of the cultivation simulation conducted in the current research are considered to represent effects from land use change as well as effects from recent technical changes.

The model explicitly addresses substitution between traditional goods (fuelwood, cattle dung, and draft animals) and modern goods (fossil fuel, chemical fertilizer, and capital such as agro machinery). Although these goods are widely used in developing countries, there are few CGE models which cover them. The author will now show that these goods play an important role in India's agriculture. Figure 1 describes the country's situation regarding agriculture. In particular, activity in the forestry and livestock sector is characteristic of that often seen in developing countries. Fuelwood accounts for more than 90% of lumber volume, and 70% of the output value in forestry (FAO 2000, GOI 1998). 70% of the rural population and

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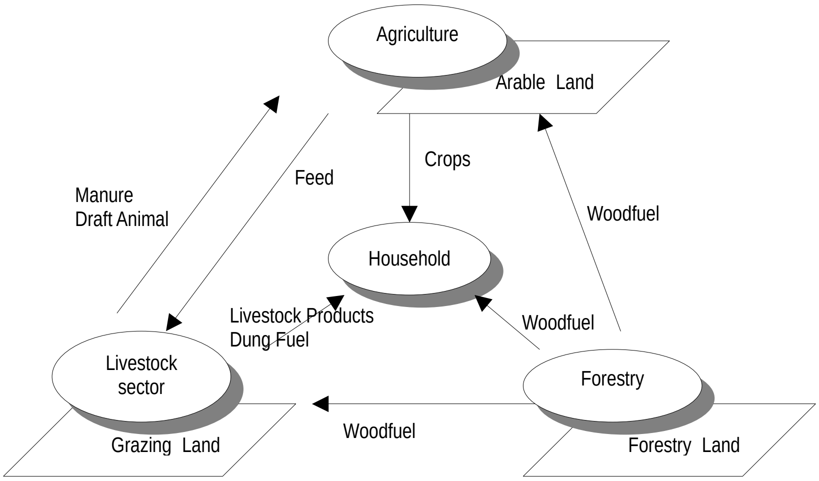
50% of the urban population in India uses fuelwood as an energy source (FAO, 1997). Meanwhile, the livestock sector not only supplies livestock products such as milk and meat, but also cattle dung as fuel used in households. And manure and draft animals are also supplied to the agricultural sector. Agriculture in India features the use of bullock carts for transport and cultivation. According to GOI (2000), 55 million head of cattle and 5 million head of buffalo were used for agricultural labor in 1992 alone. This means about one-fourth of all cattle and about one-fifteenth of all buffaloes are used exclusively for labor. Dung (both manure and fuel) accounts for about 10% of output value in the livestock sector (GOI 1998). In addition, according to Social Accounting Matrices (SAM), manure accounts for about one-fifth of fertilizer expenditures in the agriculture sector and chemical fertilizer accounts for the rest.

42% of energy sources in India are supplied by biomass energy like fuelwood, dung cakes, and crop residues (IEA 1999) while 33% comes from coal and another 19% from oil. The relationship between biomass energy and fossil fuel is important in the sense of global warming because biomass is carbon neutral.



2. Model and Data

The CGE model used here covers seven (7) sectors (agriculture sector, livestock sector, forestry sector, fossil fuel sector, chemical fertilizer sector, manufacturing sector, and service sector). The livestock sector features combined production of dung and other livestock products (meat, milk eggs and draft animals) according to a constant elasticity of transformation (CET) function. Therefore the model covers eight (8) goods (crops, dung, livestock products, wood, fossil fuel, chemical fertilizer, manufactured products, and services).

Each sector uses these eight goods as well as five factors (i.e. labor, capital, arable land, grazing land and forestry land) in conducting production activities. Land is a sector-specific factor; arable land is used only by the agriculture sector, grazing land by the livestock sector, and forestry land by the forestry sector. Full employment is assumed for labor and capital. A presumption is made that both labor and capital are sector-specific and immobile in the short-run, however in the long-run, they are mobile between sectors. Therefore, in the long-run, labor wages and the rental price of capital in each sector become the same, while in the short-run they differ in value in each sector. Aggregate factor supplies are set exogenously and factor prices adjust to ensure factor markets are in equilibrium. The production structure of the model is nested and sector-specific. A CES function is used to represent a substitution relationship between each factor and intermediate inputs such as wood (fuelwood) and fossil fuel; dung (manure) and chemical fertilizer; and capital (agro machinery) and draft animals. Factor and intermediate input demands are derived from first-order conditions for profit maximization: average factor prices equal their marginal revenue product. Import and export prices are determined by world prices, exchange rates, and tariffs. The demand for goods is an aggregate of domestically produced and imported goods described by a constant-elasticity-of-substitution (CES) function (Armington assumption). Each sector produces a composite commodity that can be transformed into a commodity sold on the domestic market or into an export according to a CET function.

Rural households, urban households, the government, corporations, and the rest of the world are the economic agents in the model. Households receive all of the income from the factors of labor, capital and land. After paying income taxes, a certain share is set aside as private savings and the rest is spent on consumption. With this constraint on total consumption expenditure, a consumption bundle is chosen so as to maximize a utility function of the Stone-Geary type. The result is the Linear Expenditure System (LES), where the consumer will always consume a minimum amount of each good, independent of price changes, and where surplus money from the expenditure budget is spent with constant coefficients for each good. The government and corporations are modeled as an explicit, non-optimizing agent. The rest of the world is modeled as a supplier of imports to, and a demander of exports from India. Each agent except the rest of the world saves money and aggregate savings is used for investment. The investment ratio between each of the goods is set exogenously. The model is static; investment represents a demand category with no effect on the supply of goods.

The model has macroeconomic balances: government deficit, aggregate investment and savings, and the current account balances. Government revenue depends on household income taxes, indirect taxes, transfers, and tariffs. Equilibriums of these current account balances are achieved through changes in the real exchange rate. The exchange rate affects the import and export price of tradable goods.

Social Accounting Matrices (SAM) for 1994-95 were constructed by making a few modifications to the SAM produced by Pradhan et al (1999) using data from governmental statistics and other literatures. Specifically, data regarding dung came from GOI (1998), data regarding land rent from Rajesh et al (1998), and that regarding tariffs and export taxes from GTAP (Hertel, 1997). Elasticity estimates were drawn from relevant literature. Data on the area of arable land, grazing land, and forestry land was drawn from GOI, FAO, GOI, respectively.

3. Experiments

Two scenarios were analyzed: 1 million ha cultivation, and 1 million ha afforestation. This simulation did not assume immature forests immediately after afforestation but rather full-grown forests where 1 million ha was available. Also, it was assumed in the simulation that fuelwood collection and livestock grazing were conducted concurrently in this forest because the object of afforestation programs is to produce fuelwood and fodder. Accordingly, the afforestation simulation was carried out by increasing forestry land by 1 million ha and grazing land by 1 million ha simultaneously. And the cultivation simulation was run by increasing arable land by 1 million ha. It should be noted that the terms “short-run” and “long-run” used here are not classified by the process of forest growth, but instead are classified by factor mobility.

3.1. Impact on Production Quantity and Price

Table1: Quantity and Price (% change from base)

Short-Run

	Cultivation			*Afforestation*		
	Price	Production	Consumption	Price	Production	Consumption
Crops	-1.64	0.48	0.34	0.33	0.02	0.04
Livestock Products	0.45	-0.01	-0.01	-1.37	0.58	0.53
Dung	1.97	0.14	0.14	-1.95	0.52	0.52
Wood	0.48	0.00	0.02	-3.23	0.93	0.20
Fossil Fuel	0.53	0.00	0.04	0.11	0.00	0.01
Chemical Fertilizer	1.65	0.00	0.46	-0.44	0.00	-0.19
Manufactured Products	0.45	0.00	0.03	0.10	0.00	0.01
Services	0.66	0.00	0.01	0.20	0.00	0.00

Long-Run

	Cultivation			*Afforestation*		
	Price	Production	Consumption	Price	Production	Consumption
Crops	-0.98	0.35	0.27	0.24	0.03	0.04
Livestock Products	0.23	0.10	0.10	-1.25	0.53	0.48
Dung	0.51	0.13	0.13	-1.34	0.52	0.52
Wood	0.47	0.01	0.06	-2.47	0.73	0.15
Fossil Fuel	0.38	0.07	0.12	0.16	-0.02	0.00
Chemical Fertilizer	0.35	0.31	0.35	0.16	-0.21	-0.19
Manufactured Products	0.27	0.13	0.14	0.14	-0.01	0.00
Services	0.42	0.10	0.11	0.18	0.00	0.00

3.1.1. Short-run Impact

Production: because labor and capital are immobile, production change is only seen in sectors whose lands have increased. This means that in the cultivation simulation, crop production increases and in afforestation, production of livestock products, dung and wood increases. There is no change in production in almost all other sectors, however livestock products and dung production changed in the cultivation simulation. This is because these products are an outcome of the CET function, and there were changes in the ratio of transformation. There is no change in production for the livestock sector as a whole.

Consumption: consumption increases for goods whose production increases. Additionally, consumption of chemical fertilizer increases in the cultivation simulation. This is due to an increase in fertilizer demand because crop production is increased. Although dung is also used as fertilizer (manure), its consumption does not increase as much as that for chemical fertilizer. On the other hand, in the afforestation simulation, even crop production is not changed, and chemical fertilizer decreases by 0.2%. The reasons behind this are mentioned later (in Section3.2).

Consumer prices: prices largely decrease for goods whose production has risen due to the increase of land (cultivation simulation: crops; afforestation simulation: livestock products, dung and wood). In addition, prices of dung and chemical fertilizer increased by nearly 2% in the cultivation simulation due to an increase in fertilizer demand. In particular, because dung is a non-tradable good, its price change is rather significant. Conversely, in the afforestation simulation, chemical fertilizer prices decreased by 0.4%. This is because demand (consumption) decreases whereas supply (production) remains fixed.

3.1.2. Long-run Impact

Production: similarly as in the short-run, production in "land-increased" sectors shows an increase (cultivation simulation: crops; afforestation simulation: livestock products, dung and wood). However the range of production increase is smaller compared to that in the short-run. This is because labor and capital drains from these sectors in the long-run; more detailed information regarding this will be supplied later. The production of chemical fertilizer increases by 0.3% in the cultivation simulation and decreases by 0.2% in the afforestation simulation. In the short-run, the demand for chemical fertilizer changes significantly, therefore this production change in the long-run is seen as a kind of adjustment process.

Consumer prices: in the long-run, in both the cultivation and afforestation simulations, the direction of price change remains almost the same as for the short-run, but the range of price change is smaller. That is, in the cultivation simulation, the price of crops decreases by 1% in the long-run and 2% in the short-run while the price of dung and chemical fertilizer increases by 0.5% in the long-run and 2% in the short-run. The same trend is seen in the afforestation simulation as well; the range of price change for livestock products, dung, wood and chemical fertilizer is smaller compared to the short-run. This is because the supply adjusts to the demand due to the factor mobility in the long-run.

3.2. Impact on Production Structure

Substitution: for the agriculture sector, three kinds of substitutions were formulated; 1) substitution between chemical fertilizer and dung (manure); 2) between fossil fuel and wood (fuelwood); and 3) between capital (agro machinery) and livestock products (draft animals). As CES functions were used for these relationships, the input of the goods increases relatively for goods whose prices have been relatively lowered.

Table2: Production Structure (% change from base)

	Cultivation		*Afforestation*	
	SR	LR	SR	LR
bstitution in Agriculture				
Chemical Fertilizer/Cattle Dung	0.25	0.12	-1.22	-1.19
Fossil Fuel/Wood Fuel	-0.04	0.07	-2.68	-2.11
Capital/Draft Animal	1.05	-0.19	-1.12	-0.89
Yield				
Crops	-0.23	-0.35	0.02	0.03
Wood	0.00	0.01	-1.53	-1.72

SR, LR: Short-Run, Long-Run

Table 2 shows the simulated results for these substitution relationships. First, for the relationship between chemical fertilizer and dung (manure), the value of "chemical fertilizer/cattle dung" is positive in both the short-run (0.25) and the long-run (0.12) in the cultivation simulation. This means that input of the numerator (chemical fertilizer) increases relative to denominator (manure). Meanwhile, this value is negative in the afforestation simulation (-1.22, -1.19), which means conversely that input of the

denominator (i.e. dung) increase relatively. As we saw in the previous paragraph, in the afforestation simulation, although crop production slightly increases in both the short and long-run, consumption of chemical fertilizer decreases by around 0.2%. This is caused by substitution from chemical fertilizer to dung (manure). In the same way, we can see that fossil fuel relatively increases in the long-run in the cultivation simulation and that fuelwood increases both in the short and long-run in afforestation. In the case of capital (agro machinery) and draft animals, we can see that capital relatively increases in the short-run, and draft animals increase in the long-run in the cultivation simulation. And in the afforestation simulation, draft animals increase both in the short and long-run. In summary, afforestation causes substitution from intensive or modern goods to extensive or traditional goods, i.e. "from chemical fertilizer to dung (manure)," "from fossil fuel to wood (fuelwood)," and "from capital (agro machinery) to draft animals." On the other hand, cultivation causes substitution almost in the converse direction.
Yield: crop yield decreases in the cultivation simulation and wood yield decreases in the afforestation simulation. In particular, the range of decrease for wood is large at around 1.53%-1.67%. Reportedly, recently in India there has been extensive cutting of forests, and the rate of such is said to be unsustainable (i.e. over-felling) (FAO, 1997). In such a circumstance, a decrease in wood yield means a decrease in cutting pressure, and this reduces the burden on the forest.

3.3. Impact on Households

Income: Table 3 shows that both types of land use change create increases in household income, but the range of increase for cultivation is two- to three-fold larger than that for afforestation. And when we compare rural and urban households, the range of increase in urban households is more than two times larger than that in rural households. This implies that the income gap between urban and rural households becomes wider. The reason for this is that the amount of capital owing per person is larger in urban areas, meaning that those living in urban households can benefit more from rises in the rental price of capital than rural households can. It can be said that both types of land use change lead to immediate increases in income levels because the range of income increase is almost the same for the short and long-run.

Table3: Household (Rs change in per capita)

		Cultivation		*Afforestation*	
		SR	LR	SR	LR
Income	Rural	14.3	14.9	5.2	4.8
	Urban	33.6	35.2	13.1	12.4
Equivalent Variation	Rural	16.1	14.5	4.0	3.8
	Urban	9.1	14.8	9.1	8.0

Equivalent variation: changes in economic welfare were measured using Equivalent Variation (EV). In the case of afforestation, the range of increase per capita is approx. 4Rs for rural households (both in the short and long-run), while it is around 8Rs for urban households; the figure for urban households is basically double that of rural households. However, in the case of cultivation, rural welfare increases more than urban welfare in the short-run, while in the long-run welfare increases equally for both rural and urban households. The two land use changes have contrasting effects on economic welfare in terms of the gap between rural and urban households.

3.4. Impact on Labor

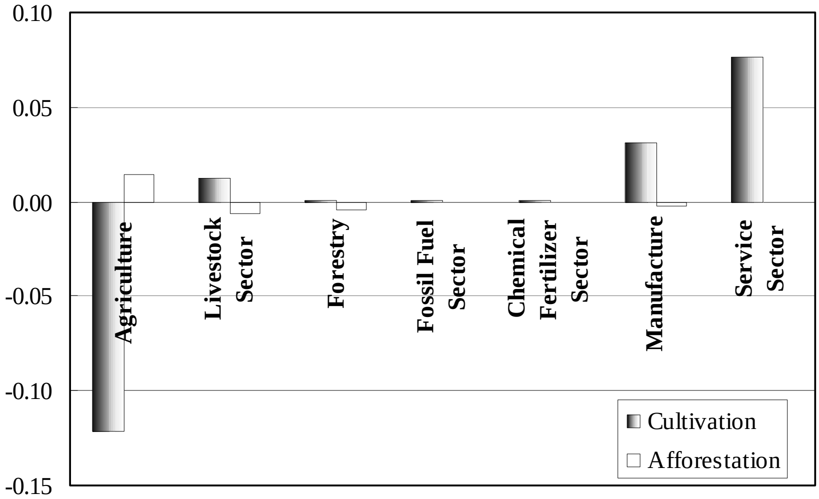
In the short-run, labor is immobile between sectors and labor wages change in each sector. These results are shown in Table 4. Wage change is almost relative to price change in the short-run as we saw in Table 1. In the case of cultivation, wages decrease in the agriculture sector and increase in other sectors especially in the chemical fertilizer and livestock sectors. In the case of afforestation, wages conversely increase in the agriculture sector and decrease in the livestock, forestry, and chemical fertilizer sectors. This wage difference causes labor migration in the long-run. Figure 1 shows labor changes in each sector in the long-run where the total labor is normalized to 100. We can see that labor decreases in the "wage-decreased" sectors and it increases in the "wage-increased" sectors. That is to say, cultivation causes labor outflows away from agriculture and inflows into the manufacturing and service sectors. As a result, labor moves from primary industries to secondary or tertiary industries. In the case of afforestation, labor conversely inflows into the

Table4: Labor wage (% change from base)

	Cultivation	*Afforestation*
Agriculture	-1.25	0.46
Livestock Sector	1.38	-0.21
Forestry	0.48	-1.11
Fossil Fuel Sector	0.58	0.09
Chemical Fertilizer Sector	5.55	-2.30
Manufacture	0.89	0.13
Service Sector	0.78	0.24

agriculture sector from other sectors, and labor increases in primary industries. The total labor movement is 0.12% in the case of cultivation and 0.015% for afforestation. We can therefore conclude that the impact cultivation has on the labor market is quite larger than that of afforestation.

Figure1: Labor Migration (Total Labor = 100)



3.5. Impact on macroeconomic indices

Real GDP increases by 0.11-0.17% in the case of cultivation and by 0.04% for afforestation. We therefore can conclude that the impact that afforestation has on GDP is very limited. And in both cases, the range of increase implies that the short-run and long-run effects on GDP are almost the same. In both cases, trade value increases and the exchange rate depreciates. These changes are larger for cultivation than they are for afforestation.

Table5: Macroeconomic Indicators

	Cultivation		*Afforestation*	
	SR	LR	SR	LR
Real GDP (Rs)	0.11	0.16	0.04	0.04
Exchange Rate (Rs/$)	0.40	0.24	0.08	0.12
Import Value (Rs)	0.58	0.45	0.06	0.10
Export Value (Rs)	0.62	0.47	0.06	0.10

(% change from base)

4. Conclusion

In this research, the impact resulting from 1 milllion ha cultivation and 1 milllion ha afforestation was analyzed using a CGE model. It was seen that cultivation and afforestation have numerous contrasting effects. The main results and implications are as follows;

The impacts on macroeconomic indices such as GDP, household income, Equivalent Variation and labor migrations are much larger for cultivation than they are for afforestation. Meanwhile, the short and long-run impacts on GDP, household income and Equivalent Variation are almost the same.

As for commodity-wise effects, naturally, cultivation increases production and consumption of crops and afforestation increases production and consumption of forest products and livestock products. Additionally however, cultivation increases production and consumption of chemical fertilizer while afforestation conversely decreases it. An interesting implication is that except for “land-increased” sectors, the sector that receives the largest amount of impact in terms of production and consumption is the chemical fertilizer sector, and there are contrasting effects from cultivation and afforestation. In the short-run, land use change causes a major fluctuation in commodity prices and labor wages. As a result, labor migration is caused in the long-run. Cultivation causes a labor outflow from primary industries and afforestation causes an inflow.

As for substitution relationships in the agriculture sector, afforestation causes substitution from intensive or modern goods to extensive or traditional goods, i.e. “from chemical fertilizer to dung (manure),” ”from fossil fuel to fuelwood,” and “from capital (agro machinery) to draft animals.” On the other hand, cultivation causes substitution almost in the converse direction.

Finally, as for environmental concerns, afforestation has environmental-friendly impacts because: 1) it decreases cutting pressure and reduces the burden on the forest, 2) through increased biomass the number of carbon sinks is increased which helps mitigate global warming, and 3) it decreases the amount of chemical fertilizer which can cause soil or water pollution. However, although afforestation causes a substitution from fossil fuel to fuelwood in the agriculture sector, it has almost no impact on fossil fuel production or consumption (sources of carbon dioxide emissions) at the national scale. On the other hand, cultivation may have a negative impact on the environment as it increases the amount of fossil fuel and chemical fertilizer.

In this paper the impacts of cultivation and afforestation were analyzed in terms of various aspects. To date, there has been little research which analyzes the quantitative impacts of land use change, and it is hoped that this paper will contribute in this area. However, this research contains certain limitations. First of all, for the purpose of simplification, the model ignores the cost of land use changes and dynamic transitions such as forest growth. Second, the agriculture, forestry and livestock sectors are not necessary separate industries in India. Many farmers engage in these activities at the same time. Modeling these realities via integration with household models or by making a village-based CGE model might be the next challenge that needs to be undertaken.

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