Brazilian Perspective on Sustainable Development of the Amazon Region

A Major Qualifying Project Report
Submitted to the Faculty

of

Worcester Polytechnic Institute

in partial fulfillment of the requirements for the
Degree of Bachelor of Science

by

Ian DeBarros

2 June 1999

Michael J. Radzicki, Ph.D., Advisor

Brazilian Perspective On Sustainable Development Of The Amazon Region

I. Preface

The present situation in the Amazon region in Brazil doesn't present itself as a new problem, but one that has existed ever since the founding of the country. The expansion of the country's population through its rough rugged interior had to aspects: to function an outflow of population out of the county's major metropolises as a type of pressure release valve; setting up military bases on the country's perimeter as to ensure national security; and on another hand, to expand and cultivate the majestic terrain that enshrouds this country. Many socio-economic and environmental problems have been caused due to this expansion into the Amazon region. It is my intention, therefore to present a simple System Dynamics model of the social, economic, and environmental structures of the Amazon region in Brazil. This innovative modeling technique has several applications, and I intend on applying this modeling technique in creating a simulation which mimics the dynamic behavior of said structures in the region in order to better understand the cause of the problems there. It is my hope that this project sheds light on the given situation, and through its simulations, helps the reader understand Amazonia's problems, and create a medium through which further study and analysis could bring a solution to an ever growing problem.

II. Introduction *"From discovery to the 20th century: A History of spasmodic occupation:"*

Ever since the beginning of the Portuguese occupation in Brazil in1500, The Amazon region has been utilized for extraction of resources and trade; such as the Amazonian rubber monopoly from 1840 to 1910.

In these 400 years of occupation, the region has undergone several social and economic changes such as: 1/ A decreasing number of indigenous people; 2/ The rubber industry of the 1840's needed a vast "contingent of almost slave labor." It is estimated that 600 to 700 thousand people migrated to the region during this stage of colonization. This influx of colonizers to the region brought about new societal contingents of: *Caboclos*, river dwellers, *Balateiros*, and *Seringerios* (rubber-tapers); who inhabit the region to this day.

The fluctuations in the level of population in the region started in 1750 by Sebastiao Jose de Carvalho e Melo, Marquis of Pombal, the secretary of Foreign affairs and War, to the King of Portugal, Jose I. In January 1750, with the signing of the Treaty of Madrid, between Portugal and Spain; custody of land in the South America would be decided upon who inhabits the regions- or effective occupation; hence the colonization of Amazonia. In July 1751, two states in the region were established: Maranhao, and Grao-Para. By 1755, the captaincy of Sao Jose do Rio Negro was established causing greater expansion in the colonization process. The Marquis of Pombal restarted the economy of the state of Maranhao and established the Royal Grao-Para & Maranhao Company, which held a trade monopoly for twenty years exporting: rice, cotton, salt, wood, and importing African slaves. In the same year, The Marquis of Pombal signed a law stating that any male colonizer that marries an Indian woman would be granted a reward in land, money, weapons, and "agricultural instruments," and would in no way be considered 'infamous.' Clandestine slavery was practiced until the beginning of the 19th century.

After Pombal's "developmental" policies were in action, the Amazonian region fell into stagnation with the Royal, or General Maranhao Trade Company's monopoly being bypassed by private individuals, with the crown's endorsement.

Another important era of transformation that came to Amazonia was due to an increased world demand for rubber; and is then subsequently named, "the rubber phase."

The beginning of steam- shipping made this "rubber phase" possible by facilitating the transportation of resources, and machine capital, but also workers for extraction purposes. In 1850, the province of Amazonas was established, and with it, a company was created with the right to monopolize steam- shipping on the Amazon river. In four years, the fleet of four ships owned by the Baron of Maua was increased to ten; and for the most part replaced the 15 ton schooners, and approximately 2000 wind, and sail powered canoes that were used to transport passengers and cargo. This manner of steam- shipping would also increase the extraction of latex. From increased production, and international demand, many fortunes were made through the rubber market, and the capital of Amazonas, Manaus, grew. But from the region's increased wealth came two sizable problems: the need for greater man power, and transportation.

In the 1870's several droughts hit the north-east region of Brazil, and through government incentives caused thousands of hungry northerners to uproot themselves to the west, where they could find work in the rubber plantations. It is estimated that 300 thousand northerners that were accustomed to living in a semi- arid region; were now faced with coping with the super- humid environment of the Amazon. Thousands died along the way on huge ships due to hunger and diseases of the region. This happened until 1920. In order to help alleviate the problem of non-shipping transportation, the Madeira- Mamore railway was built. It had been planned in 1861 in order to open new travel routes for passengers and cargo that would overcome flooded sections of the Madeira river. This project as also planned to link the Province of Mato Grosso to Bolivia. Construction of this feat would begin in 1872, with the British Company, the Madeira- Mamore Co. Ltd. In the following year, the British canceled the contract, and a North American company succeeded the British; but their contract didn't last for long either. In light of foreign companies' capacities' to finish their contracts, work was begun again in 1907, with the signing of the Petropolis Treaty (1903). This treaty stated that Brazil and Bolivia would commit themselves to finish the railway. The project was finally finished in 1912, but by then the "rubber cycle" began slowing down. The track connected Porto Velho, the capital of Rondonia (Brazil), to Guajara-Mirim, to the banks of the River Guapore on the western border of Brazil. The track stretches 374km. North-easterners, Bolivians, British, North Americans, people from the Antilles, Poland, Denmark, Barbados, Spain, Portugal, Greece, Italy, France, India, and Hungary helped in the construction of the railroad. In all, 22,000 persons were hired due to the high death rate of working in the region. During the peak of the rubber cycle between 1905 and 1906, the population of the Amazonian region had risen to one million in it's 3.5 million square kilometers. Workers came to the region because the per-capita income was twice as high there than in the coffee- growing regions. The economic collapse of the region happened when foreign capital stopped flowing in, and the demand from foreign markets dropped due to the British having started growing rubber in the east. An Englishman, Alexander Wickham smuggled rubber tree seeds out of Brazil, and helped add to the failure of the economy of the region.

III. The Amazon Region after WORLD WAR TWO

After WORLD WAR TWO the Amazonian region was integrated into the national development policy. During 1952, the National Institute for Amazon Research was founded (INPA). In conjunction with this, the Museu Paranense Emilio Goeldi (1866) worked in parallel with the INPA, and proved itself to be a very important center for scientific research.

To improve the financial status of the area, the Rubber Credit Bank was transformed into the Amazonian Credit Bank

SPVEA, the Superintendancy for the Plan for Economic Development of the Amazon, was created in order to bring economic development to the Amazon region. It served as an "institutional forum" which gave priority for the region's development.

The development pattern of the Amazon region was sustainable, generating economic growth while maintaing the natural resources of the region, until the 1960's. The Plant resources were utilized by using labor intensive production methods with simple technologies using a relatively constant population of workers. Although this growth model would function well in national markets, but as soon as this model was exposed to international markets, it could not compete without greater resource exploitation, and technology. The only problem now is that the cultivation and extraction process became unsustainable. The model was sustainable because it involved a relatively small number of workers, a limited ability to change technology, and a very abundant resource base; therefore this ensured a certain balance between the environment, and its economic use.

During the 1960's and '70's, the "regional major projects" were implemented in order to establish regional development. They were: the Superintendancy for the Development of the Amazon- SUDAM (1966), and the Superintendancy for the Manaus Free Zone- SUFRAMA

(1967). During this period various projects were undertaken such as: using radar images, a large scale survey was done on the Amazon region with an emphasis on mineral resources (RADAM project); the Belem- Brasilia, and Cuiaba- Porto Velho highways; and the region underwent extensive upgrading in aerial transport, and telecommunications. In effect, a new economic model was introduced; one with industrial sectors in: mining, metallurgy, agriculture, and livestock. With this base, foreign capital (financial resources) flowed into the region along with migrants. The meshing of all these factors caused for a 9.5% growth for the region, annually. But the economic growth was a two side coin, with environmental degradation on the other side. The following thirty years after 1950, the GROSS DOMESTIC PRODUCT of the region increased from 11.3% to 37% of the GROSS DOMESTIC PRODUCT of the country.

Even though the GDP of the region has risen faster than the growth rate of the Amazonian population, the region has a per capita- income level that is about half of the rest of the country. The problematic factors that cause this are: low levels of income being reinvested in the region, and the social structure; which includes further infrastructure expansion and maintenance; and investments in health, education, etc. In effect, Part of the regional surplus is thus lost, and investment in resources and services for the degraded regions is small. What was once historically sustainable has now been converted into the exact opposite.

IV. Problems in The Region

We live in an era of scarce resources, of difficulties in expanding the national society's economic base, of saturation of facilities for storage, or elimination of society's industrial wastes, and of fragile local, regional, and international institutions which are having difficulties in dealing with an ecological crisis. The current Amazonian ecological crisis is characterized by a progressive depletion of the region's natural resource base, and a decrease in the capacity to recover the region's ecosystems. In light of the present situation, it is imperative that an ecological parameter be incorporated into government, economic, and colonization policies.

The ecological parameters have been absent from economic, political, and social considerations due to the cause of national development. We, as a global society, must come to realize that our natural resource base is a finite quantity, and that we are all voyagers in this starship we call planet Earth. If we take on the economic approach to development consistent with short-term profits, then we will strip our starship of all its available resources, and regenerative processes and we will in fact, be the cause of our own demise. The Earth's resources can be used as an engine for economic growth for all nations, but if that engine ceases to exist through destruction of those resources, then we are limiting our global, and national growth potentials and this is not logically, economically, socially, nor environmentally viable. Sustainability is the only answer, and if applied correctly, will capacitate our economies to keep producing goods and services well into the future. The survival of humanity is based on how we as humans, and passengers aboard this spaceship called Earth deal with our wastes, ecosystems, the environment, and our social systems. Sustainable development is the key to survival.

Sustainability is a concept whose precise definition changes over the spectrum of social scientists. The view that has been adopted for this project states that "sustainable development requires that population and consumption remain within the limits of carrying capacity." (Fearnside, 1997). The specific adaptation of sustainable development to this project is defined by a balance between the social, economic, and environmental sectors, such that their inter and intra development does not outstrip their individual carrying capacities. The carrying capacity defined here for all three of the above sectors are as follows:

(i) The carrying capacity for society is defined as the limit of society's ability to develop and improve their way of life, culture, and social status (eg. housing and living status).

(ii) The carrying capacity for the economic sector is defined as the limit to which goods and services can be produced in an economy before its stock of resources becomes outstripped (eg. natural resources).

(iii)The carrying capacity for the environmental sector is defined as the limit that mankind can utilize and benefit from the environment's resources before they become outstripped (eg. the number of persons and types of crops a farm can sustain).

"Self- perpetuating social and environmental malaises are caused neither by independent or causally related processes, but rather as a result of a development trend that has control over human relations, as well as over those between humanity and nature" (The Challenge of Sustainable Development: The Brazilian Report for The Conference on Environment and Development, 1992). Based on a study done by the UNEP, the two basic causes of environmental degradation are poverty and misuse of wealth. In the short-term, the poor majorities are forced to destroy in order to fend for their immediate needs, while causing the destruction of the resource base they will need in the long run. The rich minorities demand the same long-run unsustainable resource base, and transfer the costs to the poor majority. In reference to ECLAC studies, the poor are defined as those families with an income below twice the cost of the basic food basket. In Brazil, the figures for the last decades are astonishing. The most dynamic economy in the post-war era, followed by a level of economic development during the 1940-1950 period barely superior to that of the region's poorest countries, Brazil transformed itself into the eleventh largest industrial economy (and today the ninth largest), but was unable to reduce its levels of inequality. On the contrary, during its period of largest growth (1960-1980) the wealthiest 10% of the labor force had its share of general income increase from 40%-50%, and the poorest saw its share shrink from a relatively modest 17% to 12% in 1980. In urban areas, poverty levels declined from 35% to 30% during the period of 1970 and 1980, but returned to a level of 36% in 1986. In rural areas, poverty levels undertook a declining trend from the period of 1970-1980, and then remained stable until 1986. From this analysis, one can conclude that ecological problems are intimately related to social and political problems, as well as structural distortions in the economy. Brazil faces a complex problem: situations where environmental degradation is caused due to "over-development," (pollution and waste of resources) and situations where environmental degradation is caused by underdevelopment (poverty and social and economic inequality).

V. Problems with Development in The Amazon Region

A proposal for the regional industrialization of the country was put fourth by the Northeast Development Superintendency (SUDENE), and made possible the integration of the Northeast with the mid-Southern region. The integration procedure was spatially concentrated and capital intensive, thus leading to frontiers in isolated regions such as the Camacari Petrochemical complex near Salvador, Bahia, and to farming enclaves like the large irrigation projects along the Sao Francisco Valley. The regional policy created by SUDENE was revisited when regional superintendencies for the Amazon region were created (SUDAM), the Mid-West (SUDECO), and the south (SUDESUL). Fiscal and credit backing provided by the government created new forms of management that were put into action by the political and administrative structure of the states and territories involved, and thus assured that regional elites would modernize their facilities.

In the early seventies, the government's development strategy became more selective by acting on a micro-regional level, instead of on a macro-regional scale. The government's strategy brought fourth the establishment of several development poles. Perroux's "Development Pole Theory" assumes that concentrations of investment would generate capital, profits, and employment by causing these growth poles to result in the economic integration of the region with the rest of the country's economy (Becker and Egler, 1992). In Amazonia, subsidies for national and Trans-national investments favoring farming, livestock, and mining were granted. Giant highways, telecommunications, and hydroelectric networks exposed the forest, and migration was encouraged thereby providing a mobile labor force in the region. This intense technological development pattern was at its apex when the world's economy took a downfall with a global financial and oil crisis; the result of which hit Brazil badly.

Foreign debt increased enormously, and given the large magnitude Brazil's territory, its population, the extent and diversity of its ecosystems, the complexity of its productive structure, and unequal distribution of its wealth; the global crisis was added to the challenge of accelerating material development with social justice, and environmental protection. Large parts of the nation's heritage of biodiversity were sacrificed in order to make modernization possible, causing the quality of life of the population as a whole to worsen.

VI. Agricultural Expansion of Brazil's Interior

With the large scale of government and private investments in the Amazon region, an agricultural expansion was generated by the introduction of capital- intensive production methods. In the period from 1950 until 1980, the area of the farmlands in the region nearly doubled from the initial expansion by 1.67 million square kilometers.

Although there were numerous intense investments made, due to the concentration of land ownership, social disparities and the lack of social mobility in the rural sector, the modernization process was unequally distributed by type of produce and region. The use of capital- intensive agricultural production methods did not demand sufficient labor to absorb the supply of labor in rural areas, causing a migratory flow to the cities, or to Amazonia. The modernization of the region had the effect of concentrating land ownership, and the increased growth in numbers of micro- farms, of which the sizes have been constantly diminishing. In 1960, there were 1.5 million farms of about 4 hectares (1ha= $10km^2$) in size, and by 1980, the numbers had increased to 2.6 million farms with an average size of 3.1 hectares. The inequality in distribution of investments can be seen by 80% of the farming and livestock base belonging to 10% of all farms in the region. The 90% remaining farmers need greater investments in order to build a stable productive subsistence stock for themselves, and a stock for sale.

The workers now became partial and underpaid wage laborers, and the one crop system and the resulting increase in seasonal work caused much of the laborforce to become temporary or migratory workers. The production of monoculture crops suppressed the production of subsistence crops; therefore, when an increase in demand for the supply of subsistence crops ceased to be produced, in addition to low wages; this combination amounted to a sharp reduction in consumption of subsistence crops, causing malnutrition among the migrant population.

During the eighties, the already existing problems of the region worsened due to external economic shocks such as the oil crisis, the international increase in interest rates, and the fall in international prices of agricultural goods. In addition, accelerating inflation, and a deteriorating balance of payments caused internal shocks that led to a crisis in the agricultural sector. In an attempt to improve a deterioration balance of payments, and improve competition, several measures were taken favoring the export sector, such as the increased processing of agricultural products and livestock prior to consumption or export. Due to external and fiscal crisises, the availability of government programs to sustain the colonization process was drastically reduced, and by the end of the eighties, ceased to exist. The government initiated minimum price policies, but they gradually lost effectiveness- millions of farmers were stranded and helpless without government assistance. The economic crisis caused a crisis in the agricultural sector, which, at this point was leading to a social crisis in the Amazon. What were the farmers to do; if the government or regional agencies couldn't come to their aid? The answer is simple: farmers need a way to maintain their families and earn some revenue to pay for needed investments such as chemical fertilizers, pesticides, and in the case of the farms which had concentrated government or private investments- mechanization. When the cultivated land loses its capacity to sustain a crop- the farmers would cut down more rain forest, or move to another area where their crops could be cultivated. Extensive single crop agriculture, aimed at the export market, caused erosion and land degradation, which in turn created a negative feedback in the form of depleting forest and other natural resources, and the biological balance of diseases and pests. After the farmers had cut down more rain forest, and/ or settled elsewhere, the old farm is either sold to cattle ranchers or other farmers that couldn't afford better conditions.

VII. Myths About Amazonia

The commission on Development and Environment for Amazonia produced a book for the United Nations Conference on Environment and Development, which took place in Rio de Janeiro in 1992, called *Amazonia Without Myths*, which I feel, stressed some very important points about the region. Now that the reader has been presented with a much needed historical back ground for Amazonia, I will present a list of the myths surrounding the region, for to really understand the complexities of Amazonia, we must reject the falsehoods. Several myths include (i) the Amazon Rain Forest's homogeneity, (ii) the vast riches of the region, (iii) the region being the "lungs of the Earth," and finally, (iv) the region being a quick solution for national problems. (i) The Amazon's structure is not homogenous throughout. The region is comprised of a vast variety of natural, political, and social diversity (Commission in Development and Environment for Amazonia, CDEA, 1992). In fact, Amazonia's micro- regions reveal individual types of climate, geological formations, and varying altitudes, creating a diversity of landscapes. In addition, Amazonia's micro- regions contain various types of soils, and vast biodiversity. The Amazon is shared by nine countries: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, Venezuela, and French Guiana. Each jurisdiction has its own style of government and politics, as well as development, and regional economic potential based upon each countries' economic policies, and natural resource base in the region. Another 'myth' is that "Amazonia is synonymous with Brazil," (CDEA, 1992) and that the region is solely Brazil's responsibility. This manner of thinking is based on the fact that the largest part of the Amazon rain forest belongs to Brazil; the Amazon River begins in Brazil; and finally, the superficial knowledge that exists of the region itself, on an international level. Ecuador an neighboring Peru, have the largest population density of the nine countries, and they push their lands in the Amazon to the greatest use through timber extraction. Along with other destructive activities, the countries outlined in the east by the Andes Mountains exploit the high elevations , and the mountains causing soil erosion, which leads to sedimentation, and contamination of rivers and lakes; in addition, they destroy further biodiversity through squandering their hydro- energy reserves. These actions take place in equal, or lesser magnitude in Brazil, but nonetheless, Brazil has carried the entire blame for the destruction which occurs in the Amazon region.

(ii) Due to the unimaginable variety of tropical vegetation, Amazonia was believed to posses some of the richest soils on the planet, and took on the face of an agricultural utopia, where the environment provided all that was needed for subsistence. This misunderstanding proved to be a considerable reason for the colonization of the region. Given that between all of the nine countries, several thousands of hectares of land cleared for farming have been abandoned, one can see that the soils are not as fertile as previously thought.

(iii) One of the most common misunderstandings about the Amazon Rain Forest is that it is believed to be the "lungs of the world." People fail to recognize that three quarters of the Earth's surface is water, and that vast quantity produces the majority of the oxygen we breath. Furthermore, a mature forest's carbon dioxide absorption rate is nearly the same as the rate of oxygen produced. This is illustrated in the following calculations: (CDEA, 1992)

a) It has been found in studies that the Amazon Rain Forest absorbs 2.8 kilograms of carbon, per hectare, per hour; the soil of the region absorbs 1.8 kilograms of carbon, per hectare, per hour; the trees absorb 1.0 kilograms of carbon, per hectare, per hour (Wofsy et al., 1998); and finally, the Amazon River absorbs and transports about $36\text{x}10^{-6}$ gigatons of carbon each year (Richey, et al., 1990).

b) Assuming that the loss of carbon occurs naturally; without human intervention, the standardized forest area of 640 million hectares absorbs approximately .15 kilograms of carbon, per hectares, per day. Given the following chemical equation for the photosynthesis reaction for plants:

$nCO_{2\,(g)} + nH_20_{(liq)}$ -> $(C_nH_{2n}O_n) + nO_{2\,(g)}$; 12 grams of carbon, when reacted, produces 32 grams of oxygen. Therefore, bearing in mind the total oxygen production in the Amazon Basin, an approximate $96x10^{-3}$ gigatons are produced here, or about $8x10^{-8}$ percent of the globe's total oxygen production. Through this illustration, it could clearly be seen that the Amazon Rain Forest is not the fabled lungs of the Earth (Victoria, et al., 1990).

(iv) The Amazon region is not a "panacea for national problems," (CDEA, 1992) as could be seen by the difficulties that past colonization projects experienced, and Amazonian history. With the modern development strategies for the region, and the numerous diseases which attack men and crops; Amazonian colonization did not relieve the social and economic pressures that existed in the Brazil before; it made them worse, and spread them to a region where they previously did not exist. The problems of this region will only end with reforms on a social, economic, and political level.

VIII. An Overview of The Amazon Region

The Amazon River Basin covers about 7% of the Earth's surface, and enshrouds about 7 million square kilometers of the northern region of South America, including the Tocantins and Araquaia River Basins. The rain forest itself has an area of approximately 5.5 million square kilometers. About 60% of the rain forest is situated in Brazil. The Brazilian Legal Amazon consists of about 60% of the country, and is distributed through the following states: Amazonas, Amapa, Acre, Mato Grosso, western Maranhao, Para, Rondonia, Roroima, and Tocantins. In this area, 36% of the region contains dense forest growth, 36% contains non- dense forest growth, 14% contains savannas and natural fields, and the remaining 12% consists of human occupied territory, secondary vegetation, and agricultural and livestock cultivation lands.

Even though the rain forest is home to more than half of the world's biological wealth; it contains about 2,500 known species of trees, 250,000 plant species, 751,000 species of insects, 41,000 vertebrate animals, and the remaining 1.4 million species are invertebrate animals, fungi, algae, and microorganisms. The Amazon River alone is responsible for 15.4% of the unsalted water that flows into the planet's oceans, and is a key filter for absorbing carbon, which increases greenhouse gasses in the atmosphere. Even though the natural primal productivity of the forest is high, its ecosystems are fragile. The forest's productivity and equilibrium is dependent on the recycling of nutrients and natural chemicals, which is in turn dependent on the biodiversity and the structural composition of the forest itself.

What was once thought to be a lusciously fertile region where part of the agricultural sector of the Brazilian economy could easily germinate into a massive engine of growth was later proven by experience to be false. The soil itself is moderately fertile only in certain small patches scattered about the region, because the rest is not capable of sustaining agricultural activities for more than a few years. After the terrain is depleted of soil nutrients and capability to allow for agriculture, it is in turn used for pasture; in which soon thereafter will no longer be able of sustaining feed for cattle. With this degrading cycle, more terrain must be used up for farmland and pasture. This degrading cycle unfortunately feeds the economy of the region with short- term returns , and exponentially growing unsustainablility. This cycle must be stopped before the region's vast natural wealth is lost to unsustainable agricultural methods. This change must involve a reform in the agrarian, social, transportation, and investment sectors.

In retrospect, the present situation in the Amazon region in Brazil does not present itself as a new problem, but one that has existed ever since the founding of the country. The expansion of the country's population through its rough, rugged Amazonian interior had three aspects: to function as an outflow of population out of the country's major metropolises as a type of pressure release valve; setting up military bases on the country's perimeter to ensure national security; and finally to cultivate and harvest the natural riches of Amazonia and use them in order to forge an engine of growth for the region and country.

This engine of growth we call Amazonia, must succeed in accomplishing what has not been done elsewhere: creating a form of human development that is socially just , economically viable, and environmentally sound- a sustainable economic system. This must be accomplished by designing better technologies that are not harmful to the fragile ecosystems and biodiversity of the region. Conservation zones, economic zoning, and sustainable economic policies directed at the individual 'chemistry' of each zone must be carried out at a more substantial level.

Although Amazonian soils limit agricultural output, certain regions of the territory are sufficiently fertile to maintain agriculture. The key here is to capitalize on this fertility and apply sustainable technologies, or production methods to these regions. This is where agroforestry becomes an important tool, where the recovery of degraded land could be accomplished through reforestation, and agroforestry agricultural methods.

IX. Agroferestry Systems Planning for Amazonia

"Agroforestry systems (AFS) are methods of preparing and using terrain in which trees and shrubbery are utilized along with agricultural crops and/ or animals, simultaneously in the same area, or in a temporal sequence" [Jean Dubois, Manual Agroflorestal para Amazonia]. The key in designing a particular AFS is to create an "agricultural consortium," such that the individual elements that makeup the AFS maintain the fertility of the soil within the system, and allow the agroforesters to extract and use part of the system to create products for sale and for their own use. A similar application has been in practice for hundreds of years with the indigenous tribes within Brazil, and their agrarian survival validates the possibilities for success in agroforestry systems.

There are several different types of AFS's; the most common are:

1/ Silvi-Agricultural AFS: A silvi-agricultural agroforestry system is characterized by the combination of trees, and/ or shrubs, and agricultural crops. One such system consists of: a pupunha fruit tree, a cupuacu fruit shrub, castanheira-do-Brasil (a chestnut tree indigenous to Brazil).

2/ Silvi-Pastoral AFS: A silvi-pastoral agroforestry system is characterized by the combination of trees, and/or shrubs, and herbaceous plants, and foraging animals. A simple example would be a pasture with a castanheira-do-Brasil tree.

3/ Agrossilvi-pastoral AFS: An agrossilvi-pastoral agroforestry system is characterized by a combination of both a silvi-agricultural, and a silvi-pastoral agroforestry systems. One kind of such a system would be ideal for the raising of pigs.

Any particular agroforestry system will mature in a given time, and if desired, can be developed into more complex arrangements; such as converting a silvi-agricultural system into a silvipastoral arrangement.

X. Agroforestry and The Socio-Economic structure of Amazonia

Even though the poor farmers who live in the Amazon region are relatively better off than the poor living in large cities, they are still; none the less- poor, with a low family income. These persons will not be able to afford to pay for extra hands on the farm, nor have sufficient funds to obtain adequate fertilizers, and other investments for their farm. Agroforestry systems are imperative for poor farmers, because of their general overall low costs of maintenance, and investment. Depending on their cost, government agencies might even be able to encourage agroforestry by selling the farmer inexpensive agroforestry system kit, which include all the prerequisite equipment for the kit's implantation and general maintenance.

One common trait between agroforestry systems and the rain forest is that they both function very similarly. As we already know, the soils of the Amazon region, especially in Brazil, are not very fertile and conducive to farming, yet the rain forest has such a lush biodiversity, how do the trees survive then? The answer is quite simple; the recycling of nutrients. The surface layer of soil is nutrient rich from all the fallen biomatter on the ground, from the trees themselves such as fruits, and leaves; not to mention other nutrient rich deposits which come from other biological sources within the forest. The trees in a way, create a means for their own existence by absorbing the nutrients from their own fallen leaves, and with other surrounding nutrient deposits within the vicinity. An agroforestry system works in the same way. All the individual components give and take from each other in a balanced fashion so that a stable equilibrium of nutrient recycling and usage occurs. It is this capability of the agroforestry system that allows for the recuperation of exposed soils, and the possibility of reclaiming previously used territory.

How does deforestation and the present farming approaches destroy the ecosystem? As soon as a section of rain forest is cut down, the nutrient rich topsoil becomes exposed to the elements. The rain water which would previously be absorbed by the trees, now strikes the fragile bare soil, and carries away what precious nutrients were there before. After a while, of being exposed, the soil becomes compacted, and then loses its capability to absorb any further nutrients. The soil has now become eroded and cannot be used any further. In future rain falls, quantities of this soil will then be carried away by the rain; thereby exposing more soil which will follow the path of the soil which was washed away before it and be drained into nearby rivers or lakes, where it will ruin the fragile balance of the ecosystems in these bodies of water. Furthermore, deforestation can reduce the amount of rain fall in a section of rain forest, which would lead to greater regional droughts and occasionally, massive regional flood. It is because of these problems that solutions to them are desperately needed and why the theory behind the Amazonia system dynamics model provides a good platform from which to study the growing problems of the Amazon region.

XI. An Introduction to System Dynamics

System Dynamics is a modeling technique which involves simulating high order non- linear differential equations; which are impossible for mathematicians and scientists to solve mentally; thereby needing the aid of a computer.

Quite simply, system dynamics is based on the concept of accumulators and flows. In essence, complex social, economic, and even biological systems can be modeled in this way. This field was created in 1956, by Jay Forrester, who since then has created several important and famous models that have been published in Industrial Dynamics [1961], Urban Dynamics [1968], and World Dynamics [1971].

Dynamic systems are deceiving, and a simulation will often show that the core to a system's problems could be caused inadvertently by that system's own internal response or defense actions. Understanding this deceiving nature is the key to implementing correct policies or changes in any dynamic system- be it a super economy, or a person's physical organism.

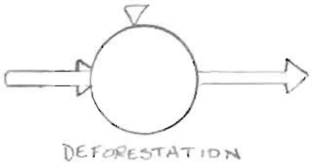
The system dynamics approach to modeling is different than the standard econometric techniques. Econometric systems are based on the statistical analysis of data, with a structural dependence on exogenous time series data to run the dynamics of the model. From the system dynamics perspective, econometric models are essentially curve fitting models which do not contain feedback structures that create dynamic changes in real systems. This field is based on 'structural thinking,' where the basis is focused on the causal structures that produce the observed behavior of a particular system.

So that the reader can have an understanding of the Amazonia model to come, the building principles of this modeling technique will now be introduced in a simplified manner.

1.) This is the symbol for an accumulator, or stock:

Stocks represent accumulations which can flow; therefore it is a variable, an equivalent representation for a stock can be thought of simply as a container with fluid inside it. Stocks are denominated in 'stock units,' or in the case of the Amazonia model, hectares, for the stocks of land.

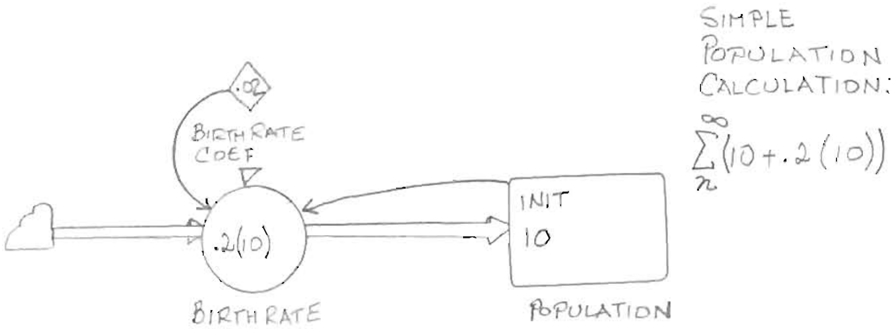
2.) This is the symbol for flow:



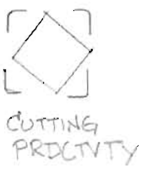
Flows represent the change in a stock in relation to time; therefore it too is a variable. Going back to our previous example of a container with water, a flow could be represented here by a leak from the container. This leak will drain the container of its accumulated fluid content. This leak can be measured as the rate of seepage of fluid from the container in relation to time; such as liters/second, for example. In the Amazonia model, the rate at which deforestation occurs can be thought of as a leak from the stock of rain forest; therefore the correct unit for a flow of this type in the model would be Hectares/Year.

3.) This is the symbol for a constant:

A constant is a specific value which can be used in unison with stocks and flows, which does not change in value. The example below will help the reader understand this point.

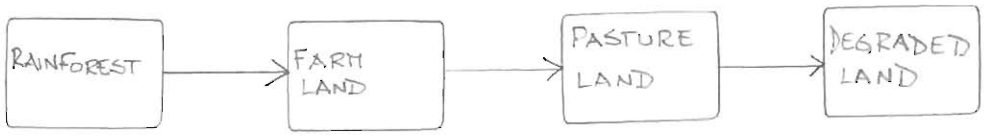


4.) Lastly, any symbol with four corners around it signifies that this a copy of the symbol inside. For example, the constant for the cutting productivity has several uses in the model, therefore, several copies of that constant will be needed, and they will look like this:

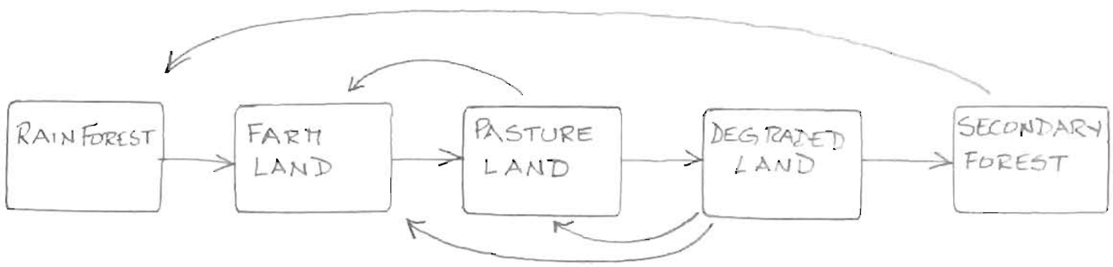


A system dynamics study begins by obtaining a description of a problem, and then classifying the problem's variables as stocks and flows. Next, the nature of the problem must be analyzed, so that logic structures can be created that describe the dynamics of the functions within a specific problem. Of course, for the unknowledgable in the field, this is easier said than done, so I will explain how the Amazonia model was built.

The Amazonia model was started by analyzing the various out- flows from the stock of rain forest. Next, a means was needed to describe these out- flows, and the best way so far was just to use constants. The following step required showing where the stock of rain forest was going to. As was in Amazonia, and for the simplified model in this project, rain forest was being cut down to clear land for the cultivation of crops, and pasture. This now, is where the story gets complicated. A simple representation of the stages through which rain forest land passes is as follows:



A more complete version of what is shown above, is what was constructed in the Amazonia model. Here it is theoretically capable of recovering, and recycling previously used lands so to minimize wasted land, and maximize farm production. This version of the model offers the possibility of a sustainable usage of pasture, and crop cultivation lands in order to minimize degraded land accumulations. How likely this is to happen is not yet known, theoretically agroforestry could be used here in order to maintain lands, but the model as a whole is purely theoretical, and does not mean that forest land is actually being fully converted. The possibility is open in the model for research and study purposes only. Below is this more 'complete' diagram:



What must now be added to the model are logic structures which would control the flows in the diagrams above. Assuming that the population of the Amazon region abide by microeconomic logic; a microeconomic logic structure can be created here. These logic structures will control how much land is cut down for either crop cultivation, and or pasture land for cattle; based on the farmer's expected revenues from each production type. It is assumed in the presented model that there is no extraction of trees by domestic and foreign companies in order to simplify the logic structures.

XII. System Dynamics as a Basis for The Amazonia Model

XII.I Creating The System Dynamics Model for the Amazon Region

The model created for this project is a combination of three main sectors: the Amazonian economic sector, the demographic sector, and the Amazonian environmental sector. Full dynamic modeling for the government sector will not be included in this project in order to keep model simple, and to keep the project focused on the problems within the above three sectors, not regional politics. Introduction of the government sector would be more viable in a greater detailed model in order to account for delays in policy formulation, and implementation, for example. The activities of the rural economic and demographic sectors of the Amazon region are the main factors of the cause of environmental destruction In Amazonia. The causes which lead to destruction are: the harvesting and cultivation methods of farms, which represent the rural economy, are unsustainable; the multitude of farms and ranches, which are directly related to the rural population, exacerbate the rural area's carrying capacity; and the extraction of trees by foreign and domestic companies. The extent of the modeling done here though, does not focus specifically on the extraction of trees by companies, because we are interested, at this time, to study the microeconomic logic governing the households, and their direct effect to deforestation in the Amazon.

12.2 Application of Micro-Economic Theory to the Amazonia model

In this model, each farm will consist of a household, and each household is assumed to behave and exhibit the microeconomic characteristics of a firm, with the household's greatest motivation being profit and returns maximization. For simplicity in the model, it is assumed that the households will produce only two types of goods: agriculturally produced crops, such as corn, rice, beans, etc., and beef production from cattle ranching. With two types of goods being produced, the households will have to decide how much of each good they will need to produce in order to maximize their returns. This in turn, will be based on a production function containing the following factors: available household labor, the size of the plot of land available, the input costs for each of the two types of household goods produced, and the land degradation rates caused by each type of production.

Using the logical framework established by John Sterman in his paper entitled: "The Use of Aggregate Production Functions in Disequilibrium Models of Energy-Economy Interactions," a similar approach can be applied to the Amazonia model, where a production function framework will be created which is suitable for disequilibrium modeling of land use. As in Sterman's paper, a production function would not only include a determination of output from the quantities of input factors, but also the relative desirability of using various combinations of production, the dynamics of the substitution process for the input factors, and a generation of derived demand for the various input factors. The modeling will be studied and conducted in both static and dynamic reference frames.

For the purpose of this project, Cobb-Douglas type production functions will be used. Throughout the project, two outputs will be studied, one output for crops and one for ranching. Each of these goods produced will be described by a single output, two factor production function; in which the factors vary for each output. The crop production function will have land for agriculture and labor as factors of production. Here, the variable for agricultural land in use for crops is called 'Farmland,' and the variable for the labor force that participated in the production of corn is called 'FarmLabor.' The ranching production function will have land for pasture and labor as its factors of production. 'Pastland' is the variable for the amount of land used for raising cattle, and the variable, 'PastLabor,' reffers to the laborforce that participated in beef production. The reader will note that the sum of both types of labor represents the total labor force for the individual house hold. In Amazonia, the farmers will select a fraction of their cross- trained labor force to function accordingly to the house hold production function; which would account for the following types of work: cutting a preset quantity of forest land for either crop, or beef production, and the tending of cut forest land for either crop or beef production.

Since each plot of land will be divided into a certain fraction of pasture, and farm land, the producers must decide how much to produce from each fraction of land, such that revenues are maximized. In some extreme cases, all the land will be either cut down from native forest to supply either pasture or farm land. These calculations will be done using the expected revenues for beef and crop production. From these calculations, the total land under management will have to be decided by the households, based on how much time they will have to spend preparing land for cattle and/or crop production, and this will be based on the marginal revenues for those goods. Further land will also be demanded by the households in order to replace degraded, and or degrading lands. Factor prices and demand for output here are assumed to be exogenous. Market cattle and crop prices are also assumed to be exogenous because due to the high elasticity for these goods, these firms- or in the case of this model, the households- are price takers, not price makers.

Desired and actual goals, for each factor, such as different kinds of land for different production uses, production for each good, labor, marginal productivities for the different goods produced, and marginal revenues for goods produced must be taken into account because, desired and actual beef or corn production might not be equal.

A period of time will pass before a household will come to believe that a change in the market prices for cattle and their crops will be constant enough in order for the households to rebalance their factors in their production mix. Furthermore, the rural Amazonian households, like all firms, will not be able to adjust instantaneously to changes in demand for their goods, prices for their goods, and directly related, firm demand for different land uses. Hence, an adjustment period must be taken into account in the model, during which orders for more demanded goods, and land types, are supplied. This is done through an ordering function, with correction adjustments for imbalances between desired and actual factors. This is done through the ordering rate. Consequently, these corrections to the ordering rate are representative of a non-linear function which creates a pressure to increase, or decrease the household's orders.

There will be order accumulations and backlogs, and a first order control mechanism must be applied to orders such that over-ordering and double- counting orders does not happen. All of the above orders are based on perceived demand for the household's goods, and perceived revenues; and for logical results to be obtained from the model, it must be robust under extreme conditions.

Production and factor acquisition here are based on disequilibrium modeling. The potential production of the household is defined as the production output level that can be achieved with normal utilization of the household's available factors, multiplied by the household's scheduled capacity utilization to yield the actual output rate. Scheduled capacity utilization is a nonlinear function based on the production ratio, which is in essence, a measure of demand relative to supply. The production ratio at equilibrium is equal to one. In the model here, it is a measure of the demand of the household's produced goods relative to their supply; and if the production ratio decreases below one, the scheduled utilization becomes reduced.

The described system dynamics mechanisms in this chapter reproduce the logic of a firm relating to managerial operations and functions by the rural Amazonian households. This microeconomic theory is then applied to the system dynamics 'plumbing' of the environmental sector of the Amazon region; such that the stock of native forest is depleted by deforestation by households to acquire farm, and pasture land so that they can produce beef and crops. Included in this model, are flows of stocks caused by depletion of both farm and pasture lands by degradation and erosion, and the transfer of farm lands into pasture lands. In this specific model, a simplified representation is presented, such that reinvestment by the government, environmental, and household sectors into the stocks of degraded lands, and the household's plots of land through reforestation efforts are shown, but are controlled by constants, not variables. Furthermore, the extraction of the Amazon rain forest by private foreign and domestic companies is not the focus of this project; even though, it is a major cause of deforestation.

Foreign Asian companies, for example, have already depleted their own rainforests considerably, and are now looking for another forest from which to extract trees. As their own natural supply of trees deminish, a greater emphasis toward extraction will be put on Amazonia by these foreign companies.

In the future, if this project stimulates national and global interest, a more detailed and sophisticated model can be presented.

XII.III. Dissecting The Amazonia Model

The Amazonia model is built up from three individual sections, which were later united into one whole model. These sections consist of three separate sub-models created to independently describe the demographic, economic, and environmental sectors, respectively. A machine is built of different systems, likewise, so is this model, and each system consists of its individual parts working in unison. For simplicity, all the individual parts are labeled for the reader, and in the specific case of the central part of the model, "Part 1", has color coded logic structures so that the reader can easily differentiate between them. Definitions will be provided for the variables used within the main parts of this model. The focus of most of the explanations will be based on Part 1.

The color code is as follows:

1.) Red variables represent leverage points which the government would have some control over. The main flows at these points consist of the farm and pasture reclamation rates, and the rates of secondary and rainforest formation. The government can incentivate, through several means, the reclamation of used land in order to minimize the amount of degraded created each year; and protect secondary forests so that in time, they can be transformed into rain forest. Previously used land can potentially be reused through much investment and refurbishment; but instead, is generally discarded, becoming useless. Through subsidies for farmers who chose to refurbish previously used land, and taxation of those who do not, the government would be able to manipulate farmers into reusing previously used land, as opposed to clearing more rain forest. One suggested reclamation process that was discussed before in a previous chapter, agroforestry could represent a suitable means for sustainable land usage, and recovery.

2.) The section in purple represents the first order control for the flow, 'FarmCutRate,' which represents the number of trees cut down yearly in order to clear rain forest for farm land. Below is a list of variable's names and constants and their definitions from this section:

LaborFarmCutting- is a variable which defines the number of persons whose purpose on the farm is to cut down rain forest for farm land.

CuttingPrdctvty- the cutting productivity is a constant which represents the number of hectares that can be cleared, per person, per year.

IndFarmCutRate- the indicated farm cut rate represents the quantity of rain forest that can be cut down per year; given the labor for clearing rain forest for farm land, 'LaborFarmCutting,' and the cutting productivity.

NrmRFCov- the normal rain forest cover represents the number of years that remain of rain forest, given a constant cutting rate. From an INPE data source, shown below, annual deforestation rates from 1978-1996 average 17,479 km^2, or 1747.9 ha of deforested land per year. Hence, if the initial stock of rain forest consists of 5,600,000 ha; there remains: (5,600,000 ha)*(1/ 1747.9 ha/year)= 3203.4 years remaining of rain forest, given the average deforestation rate from 1978 until 1996. Thus, 3203.4 years is the value for the normal rain forest cover.

RFCov1- the rain forest coverage represents the remaining time for rain forest coverage based on a calculation involving the stock of rain forest and the indicated clearing rate for farm land. The RFCov1 and NrmRFCov will not be equal, and a correction between both values must be made. This is done through the table function, EffRFCovFarmCutRate, the effective rain forest coverage due to the farm cut rate This function works as a "smooth" between both results, and the entire purple section works as a corrective agent by making sure that orders are not double counted, and double ordered. This 'first order control' agent is apparent on all the major flows in the model such as the farm cut rate, pasture cut rate, farm conversion rate, farm depletion rate, and the pasture depletion rate.

PastureCutRate- this is defined as the rate at which rain forest is cleared for the establishment of land for raising cattle, pasture land.

FarmConversionRate- this is defined as the rate at which land for crops is physically converted into pasture land.

FarmDepletion rate- this is defined as the rate at which farm land is depleted, or eroded. After farm land becomes eroded, it would no longer be able to grow crops, and is then generally used for raising cattle.

PastureDepletionRate- this is defined as the rate at which pasture land is depleted, or eroded. After pasture land becomes eroded, it can no longer be used for pasture by cattle, and becomes degraded land.

NrmFarmCov- the normal farm land cover represents the number of years that farm land can be used to grow crops before it becomes depleted, and unusable for that purpose.

DesFarmConversionRate- this is defined as the desired quantity of farm land that can be converted into pasture land. The desired and actual farm conversion rates may not be equal; therefore, a correction factor must be taken into account during the calculation of converted land, though this is only shown in Part 5 of the model.

NrmPastureCov- the normal pasture coverage represents the number of years that pasture land can be used before it becomes completely eroded and can no longer sustain cattle.

IndPastureDepletionRate- the indicated pasture depletion rate is defined as the amount of pasture land that becomes depleted through its use in the raising of cattle. It is a product of pasture production (PasturePrdn) and a constant which relates pasture depletion and pasture production (PrdctvtyPasturePrdnOnDepletion)

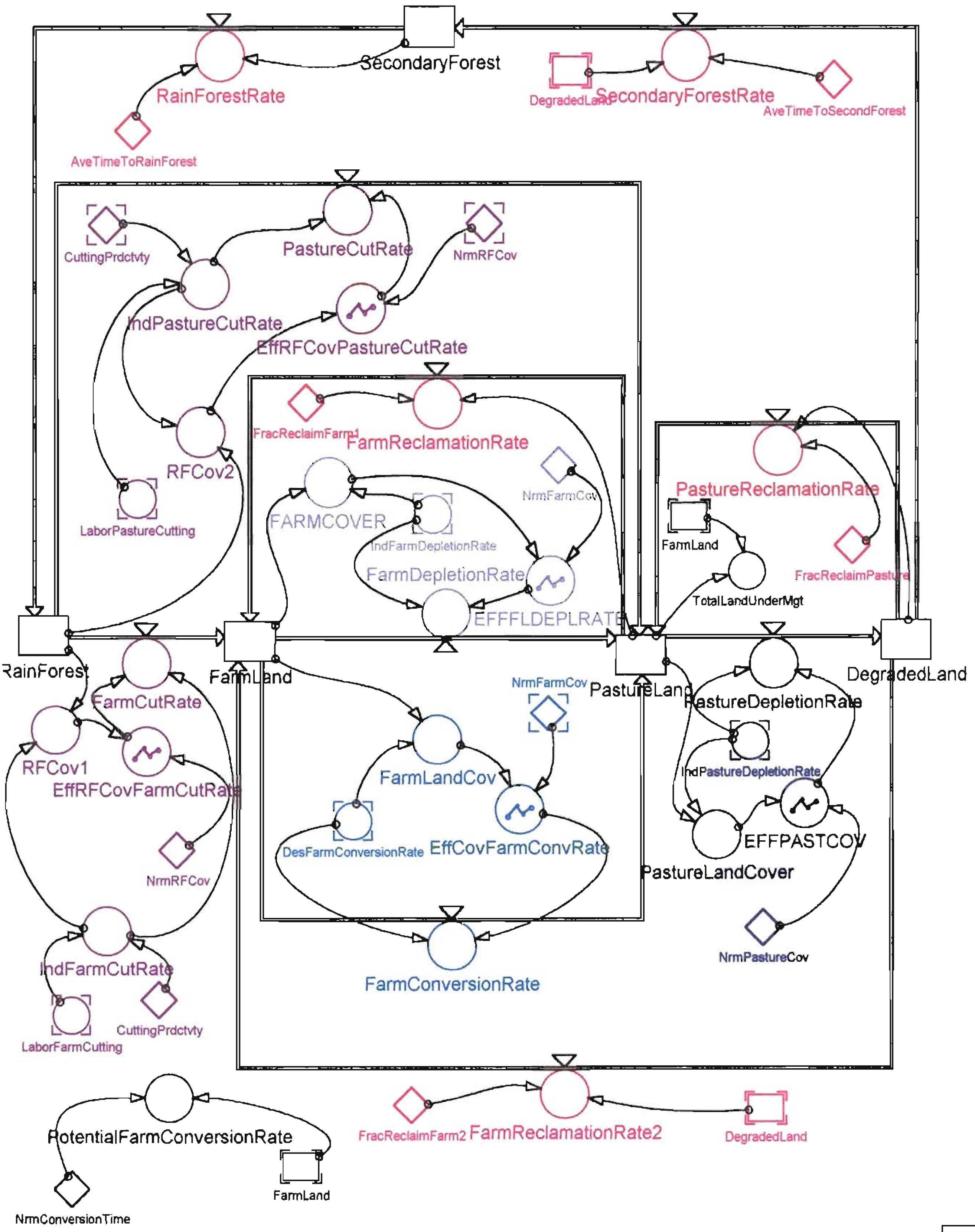
IndFarmDepletionRate- the indicated farm depletion rate is defined as the amount of farm land that becomes depleted through its use in crop production. It is a product of crop production (FarmPrdn) and a constant which relates farm land depletion and farm production.

Before moving on to the results and analysis of the model simulations, I am compelled to explain four important constants from Part 2, the demographic sector of this model.

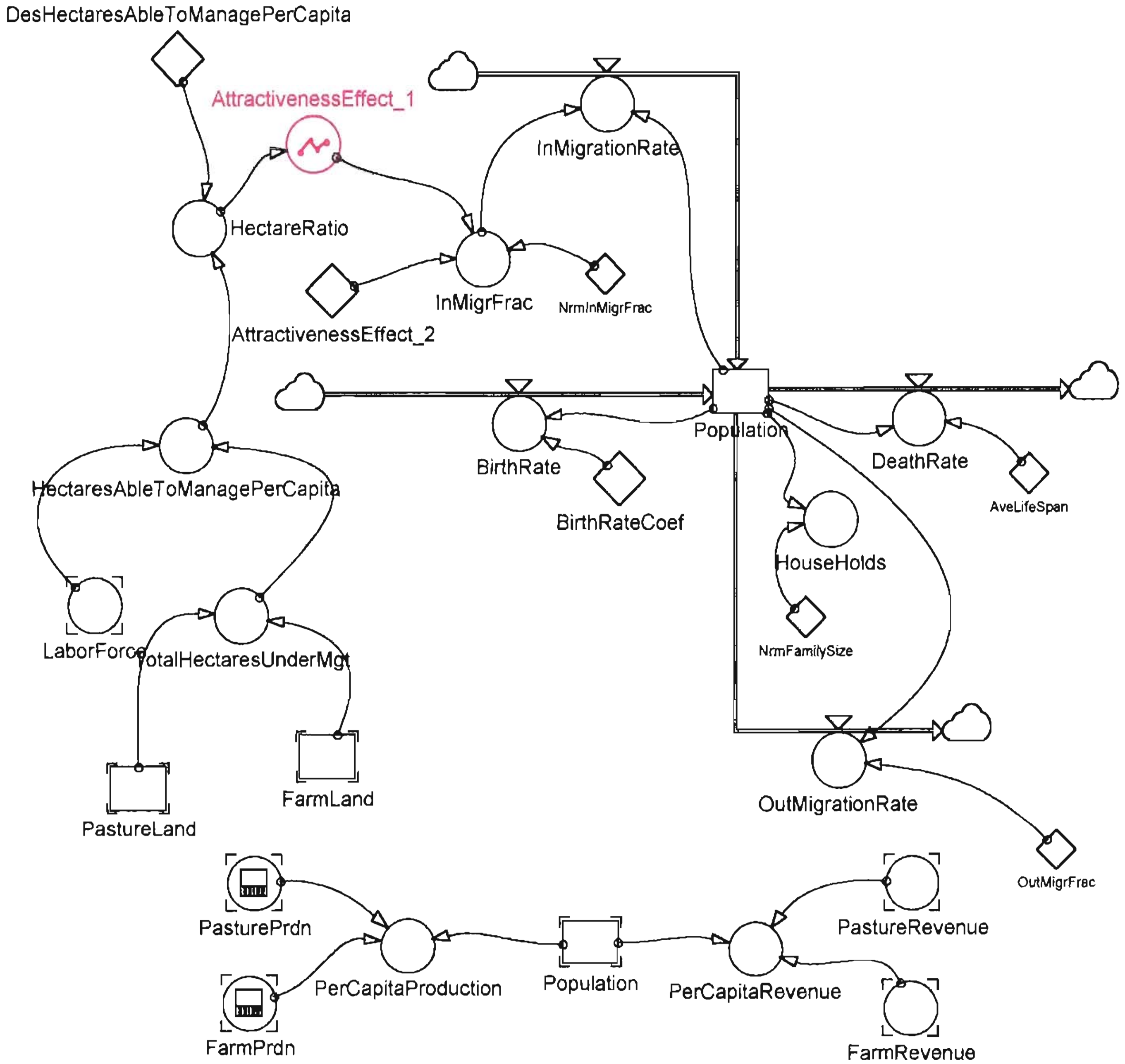
NrmInMigrFrac- the normal in-migration fraction is calculated by dividing the average in-migrated population of the region since 1978 until 1991, divided by the population of the region in 1991. Since I was unable to find a value for the in-migration into the Amazon region for 1996, my calculation was based on the average in-migrated population from 1978 to 1996.

BirthRateCoef- the birth rate coefficient was calculated by using the number of births in the region in 1991, divided by the population of the region in the same year. Thus this results in a ratio of births to the actual population, and can be used to theoretically calculate the birth rate of the population in the Amazon region, if the birthrates remain constant, and by saying that the inflow of births is the result of the product of the birth rate coefficient and the population given at any time.

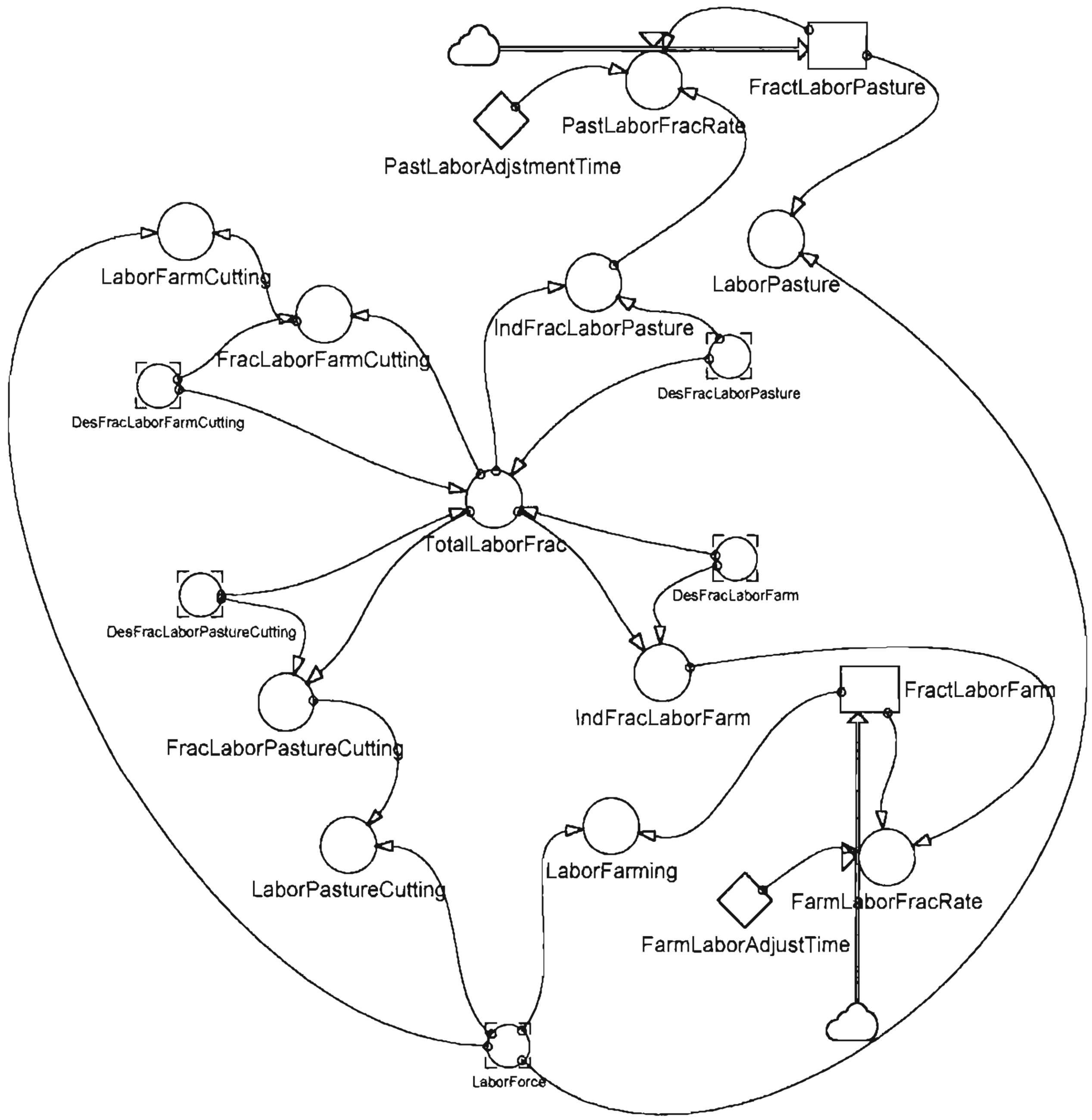
THE AMAZONIA MODEL



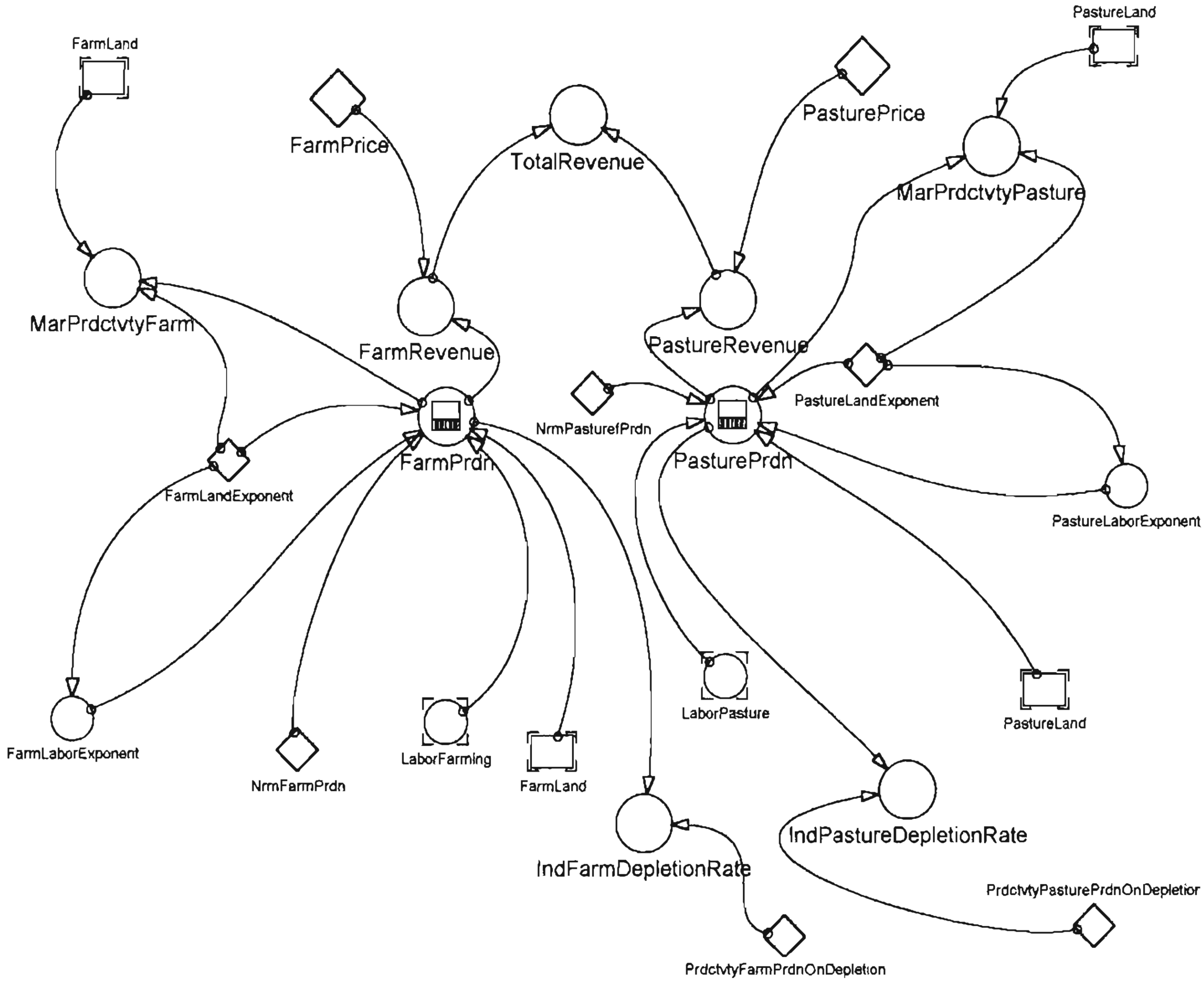
Part 1


DesHectaresAbleToManagePerCapita
AttractivenessEffect_1
HectareRatio
InMigrationRate
InMigrFrac
NrmInMigrFrac
AttractivenessEffect_2
Population
BirthRate
DeathRate
BirthRateCoef
AveLifeSpan
HectaresAbleToManagePerCapita
HouseHolds
NrmFamilySize
LaborForce
TotalHectaresUnderMgt
FarmLand
PastureLand
OutMigrationRate
OutMigrFrac
PasturePrdn
PastureRevenue
PerCapitaProduction
Population
PerCapitaRevenue
FarmPrdn
FarmRevenue

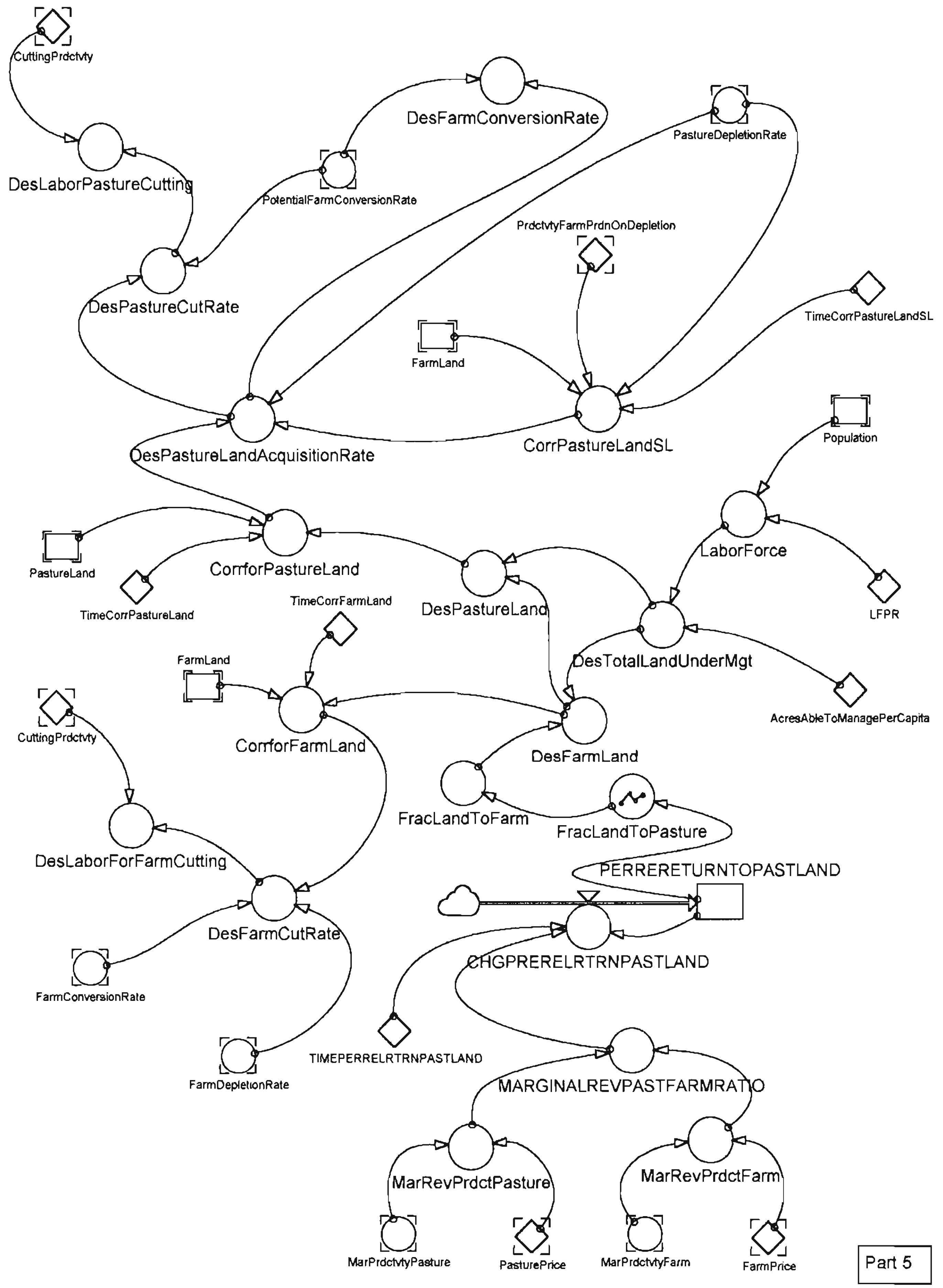
Part 2


FractLaborPasture
PastLaborFracRate
PastLaborAdjstmentTime
LaborFarmCutting
LaborPasture
IndFracLaborPasture
FracLaborFarmCutting
DesFracLaborPasture
DesFracLaborFarmCutting
TotalLaborFrac
DesFracLaborFarm
DesFracLaborPastureCutting
IndFracLaborFarm
FractLaborFarm
FracLaborPastureCutting
LaborFarming
LaborPastureCutting
FarmLaborFracRate
FarmLaborAdjustTime
LaborForce

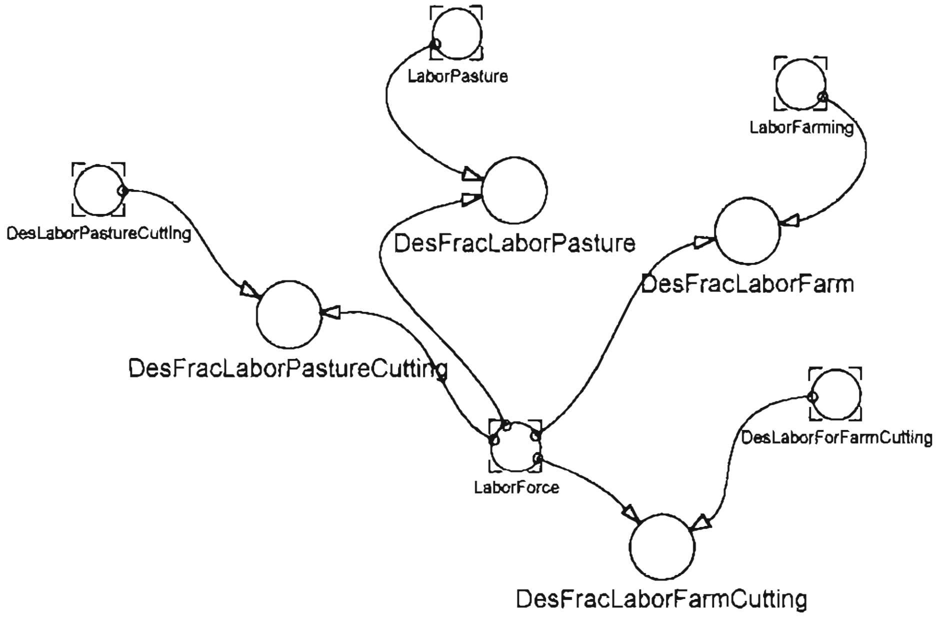
Part 3


FarmLand
FarmPrice
TotalRevenue
PasturePrice
PastureLand
MarPrdctvtyPasture
MarPrdctvtyFarm
FarmRevenue
PastureRevenue
NrmPasturefPrdn
PastureLandExponent
FarmPrdn
PasturePrdn
FarmLandExponent
PastureLaborExponent
FarmLaborExponent
NrmFarmPrdn
LaborFarming
FarmLand
LaborPasture
PastureLand
IndFarmDepletionRate
IndPastureDepletionRate
PrdctvtyPasturePrdnOnDepletior
PrdctvtyFarmPrdnOnDepletion

Part 4



CuttingPrdctvty
DesFarmConversionRate
PastureDepletionRate
DesLaborPastureCutting
PotentialFarmConversionRate
PrdctvtyFarmPrdnOnDepletion
DesPastureCutRate
TimeCorrPastureLandSL
FarmLand
DesPastureLandAcquisitionRate
CorrPastureLandSL
Population
LaborForce
PastureLand
CorrforPastureLand
TimeCorrPastureLand
DesPastureLand
LFPR
TimeCorrFarmLand
DesTotalLandUnderMgt
FarmLand
AcresAbleToManagePerCapita
CuttingPrdctvty
CorrforFarmLand
DesFarmLand
FracLandToFarm
FracLandToPasture
DesLaborForFarmCutting
PERRERETURNTOPASTLAND
DesFarmCutRate
CHGPRERELRTRNPASTLAND
FarmConversionRate
TIMEPERRELRTRNPASTLAND
FarmDepletionRate
MARGINALREVPASTFARMRATIO
MarRevPrdctPasture
MarRevPrdctFarm
MarPrdctvtyPasture
PasturePrice
MarPrdctvtyFarm
FarmPrice
Part 5


LaborPasture
LaborFarming
DesLaborPastureCutting
DesFracLaborPasture
DesFracLaborFarm
DesFracLaborPastureCutting
DesLaborForFarmCutting
LaborForce
DesFracLaborFarmCutting

Part 6

12.4 Results and Analyses from Policy Run Simulations

Several constants have been combined into control panels on the model so that they can be changed in value by the simulator, so that the simulator can run their own simulations, and draw their own conclusions from the Amazonia model.

A set of three simulations were run for this project, but before delving into them, some comments must be made about the simulating procedure done here for this project. The type of modeling done here is completely theoretical. It is assumed that the simulator can play God, and with a whisk of the slider bars on the model's control panel, one can change the birth and death rates of the population in the Amazon region in Brazil, and instantaneously change degraded and relatively useless land into secondary forests and rain forests. All the data here is theoretical, and does not necessarily represent actual or exact government figures, or policies in the region. It is my interest; therefore, to study the results from the simulations, by pushing the model to simulate conditions where some of the inputs might be extreme. This being the case, the simulations are as follows:

12.4.1 Amazonia as A Pressure Release Valve for Over Populated Cities

For this simulation, I wanted to study what would be the general result on the region if it had a very large population. Therefore, it is assumed here that Amazonia has a very minute out-migration rate, and a high in-migration rate, which would be caused be people leaving large urban centers from around the country, such as Rio de Janeiro and Fortaleza. For there to be a large inflow of people into the region, they must be attracted there, so the constant, AttractivenessEffect_2, on the control panel, was increased to its maximum value. With there being a great influx of people into the region, the regional population would increase tremendously; so the initial value for the population in this run was 50,000,000 people. Along with this, it is further assumed that the region has a high birth rate; low reclamation or recycling rates for previously used farm land for crops, and pasture land for cattle; a high value of soil depletion due to farm and pasture productivity, and a high labor force percentage (LFPR) for regional labor. The LFPR is used to approximate the region's labor force as a product with the region's population. During this and the remaining two simulations, the following constants will remain unchanged: normal farm and pasture production (NrmFarmPrdn and NrmPasturePrdn, respectively), cutting productivity (CuttingPrdctvty), exogenous regional market crop and cattle prices (FarmPrice and PasturePrice, respectively), average rain forest creation time (AvTimeToRainForest), average secondary forest creation time (AvgTimeToSecondForest), the average life span of an inhabitant from the region (AveLifeSpan), and the normal family size (NrmFamilySize), which represents how many people reside within a family in the region.

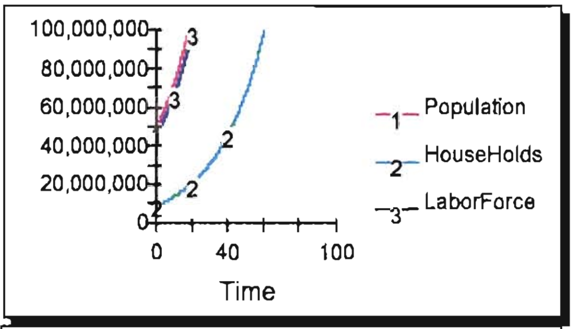
Having the basis stated for the first simulation, the results are as follows...

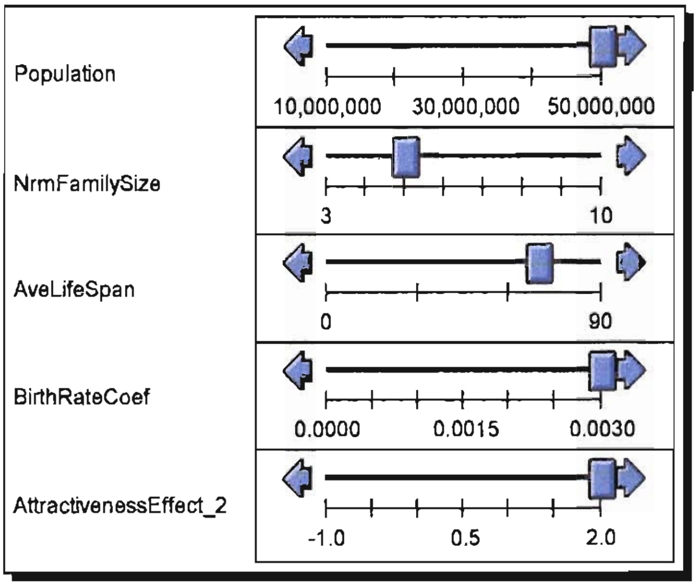
XII.IV.II. Amazonia as a "Biodome" Experiment

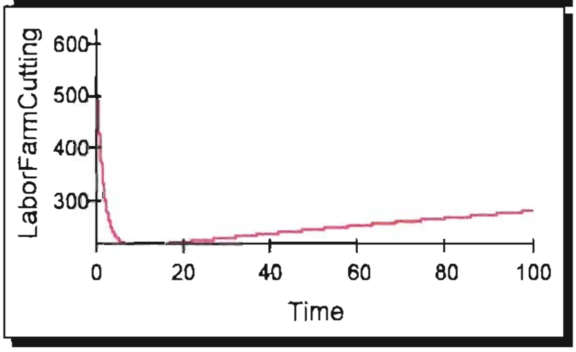
AMAZONIA AS A PRESSURE RELEASE VALVE ...

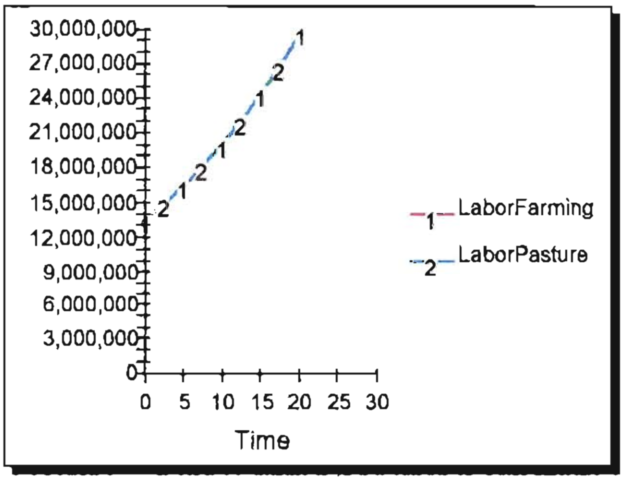
AMAZONIA MODEL CONTROL PANEL

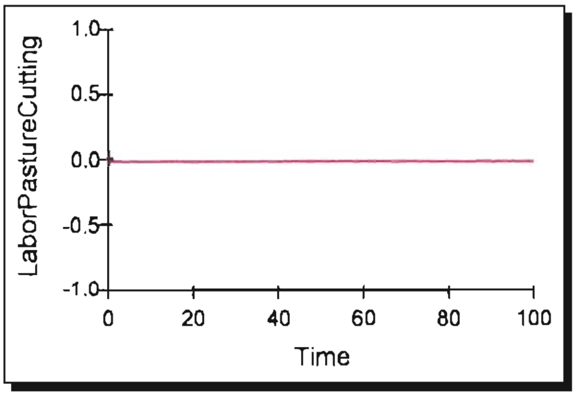
DEMOGRAPHIC SECTOR

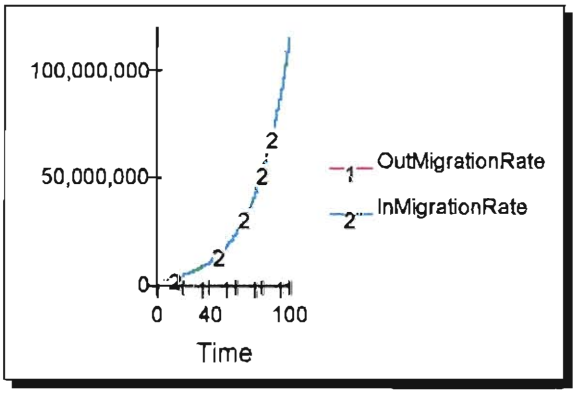


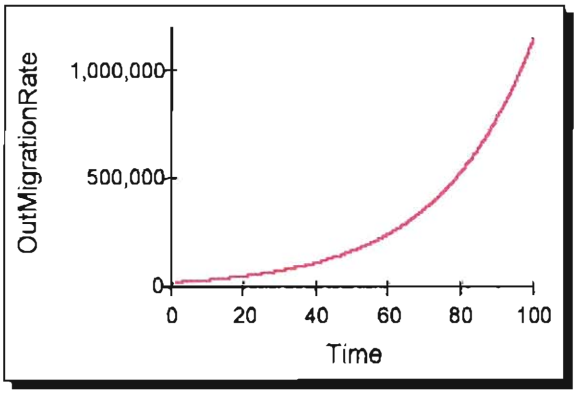




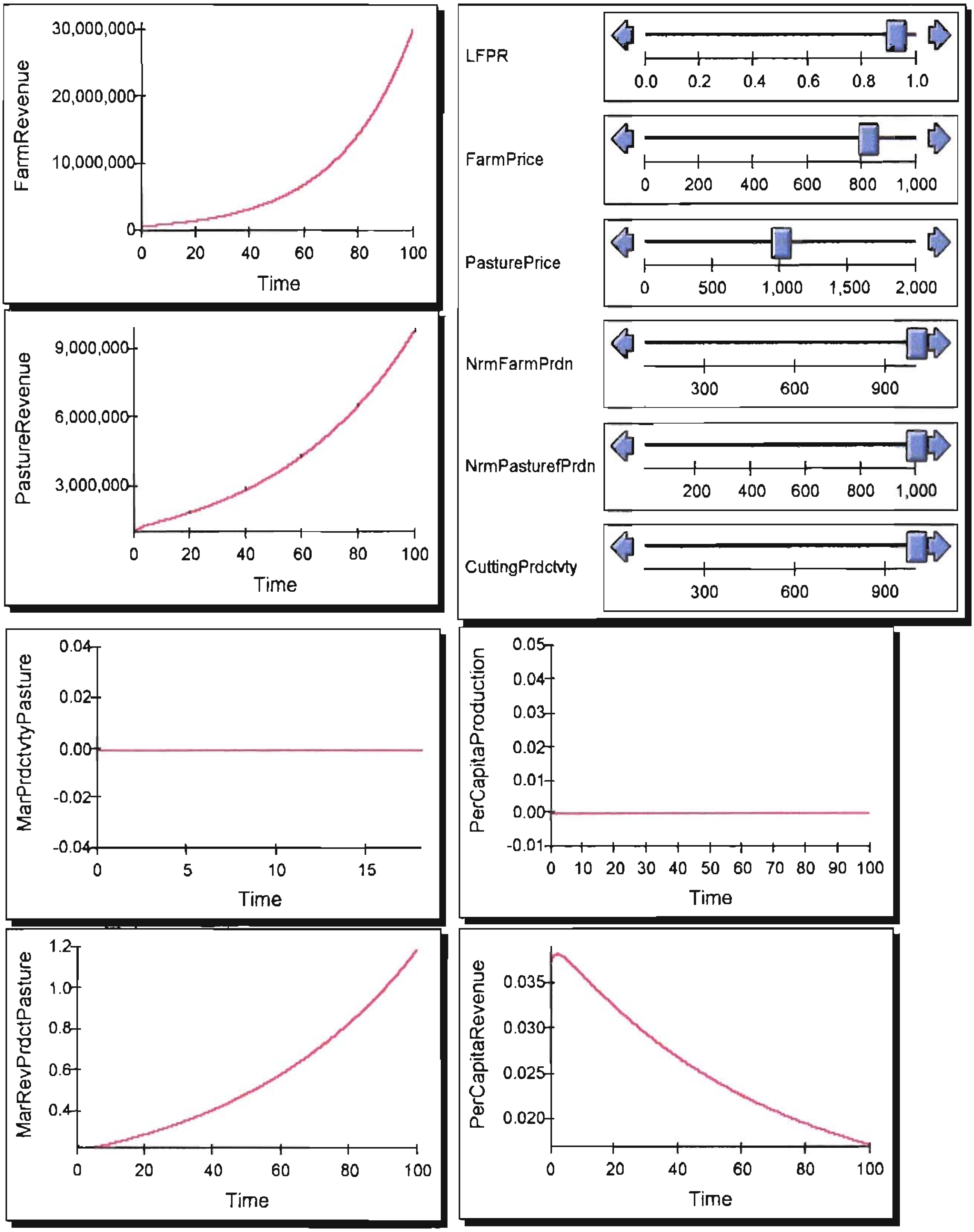


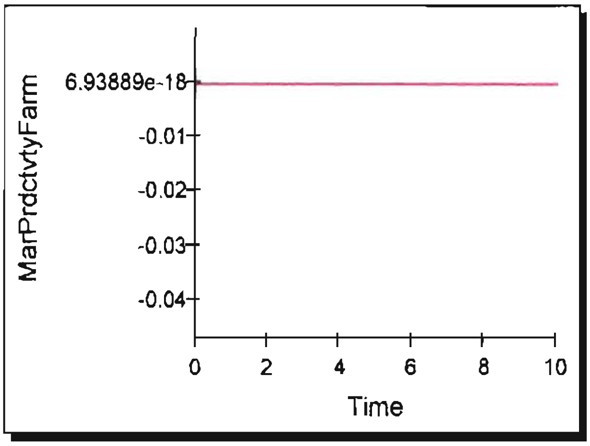


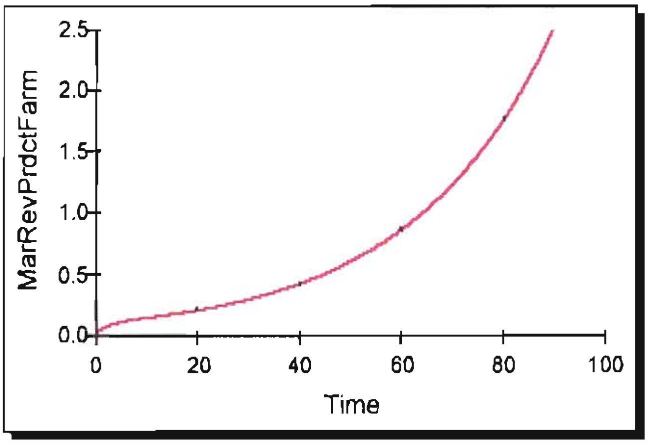




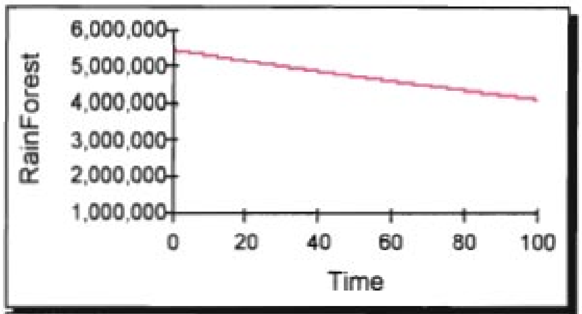
ECONOMIC SECTOR

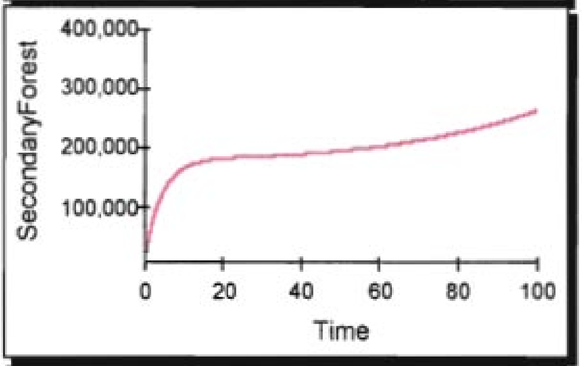


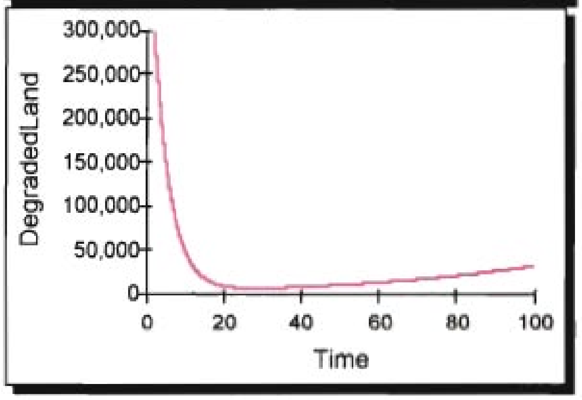

MarPrdctvtyFarm
6.93889e-18
-0.01
-0.02
-0.03
-0.04
0
2
4
6
8
10
Time

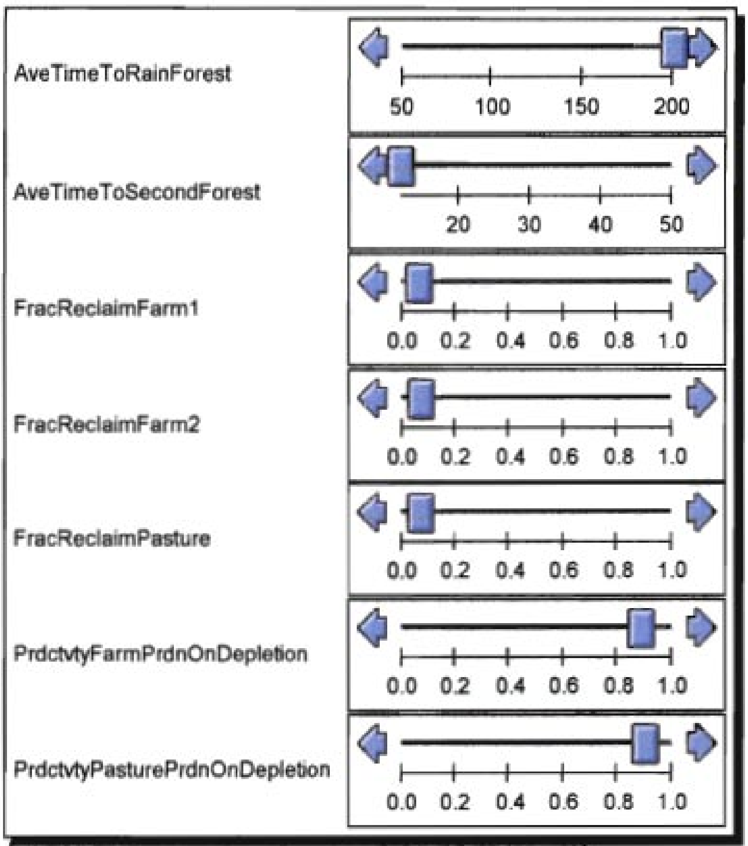

MarRevPrdctFarm
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
Time

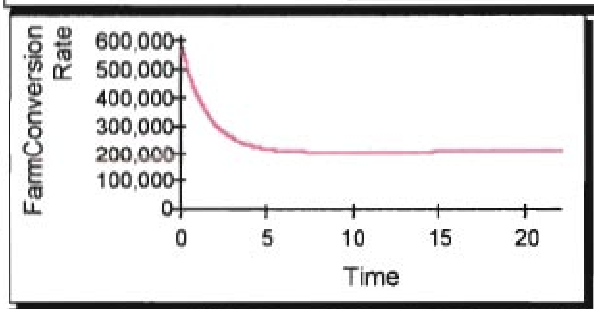
ENVIRONMENTAL SECTOR

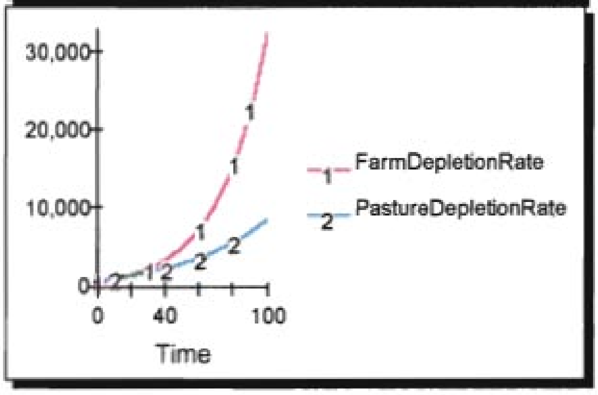


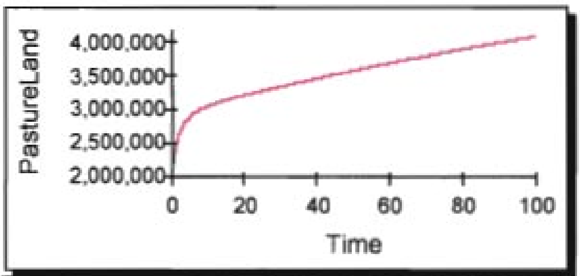


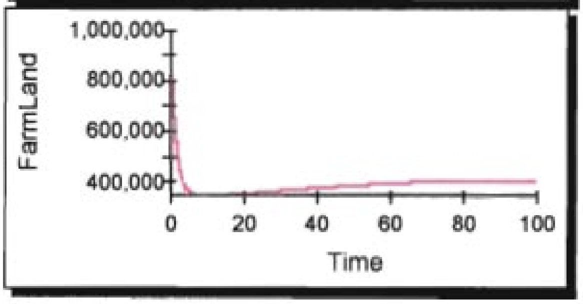


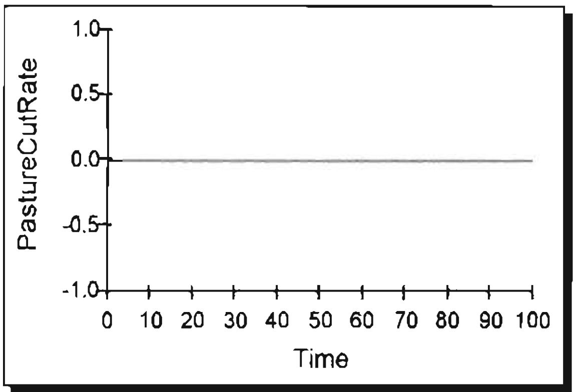


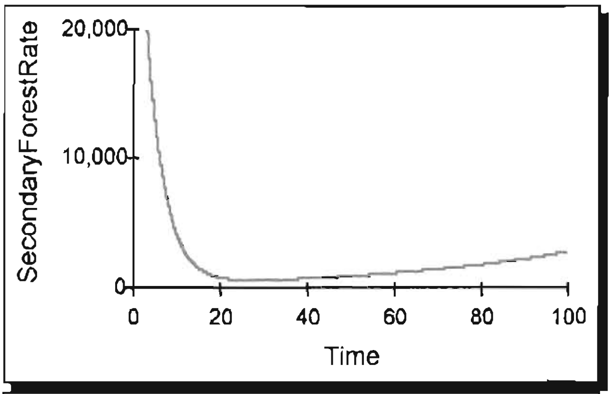


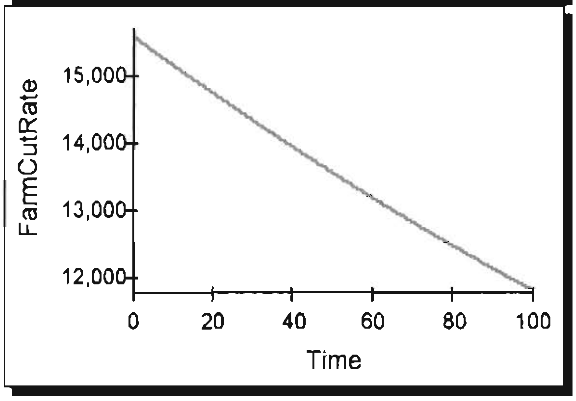


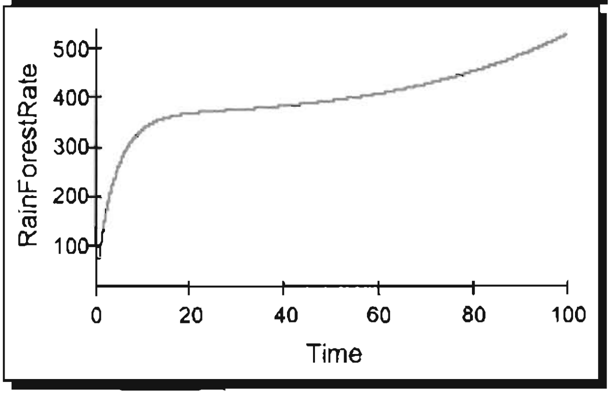


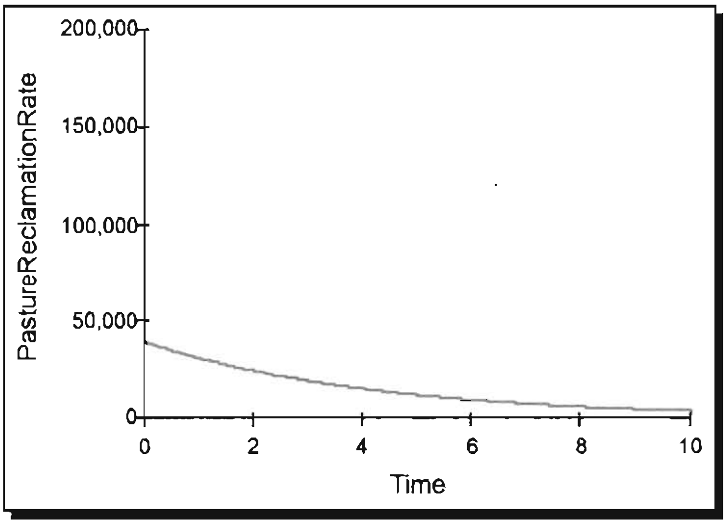


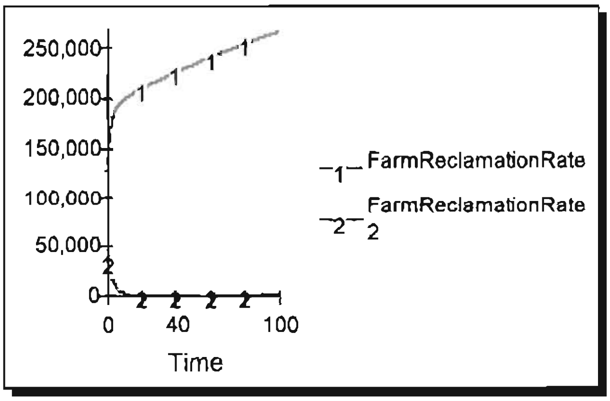

PastureCutRate
1.0
0.5
0.0
-0.5
-1.0
0 10 20 30 40 50 60 70 80 90 100
Time


SecondaryForestRate
20,000
10,000
0
0 20 40 60 80 100
Time


FarmCutRate
15,000
14,000
13,000
12,000
0 20 40 60 80 100
Time


RainForestRate
500
400
300
200
100
0 20 40 60 80 100
Time


PastureReclamationRate
200,000
150,000
100,000
50,000
0
0 2 4 6 8 10
Time

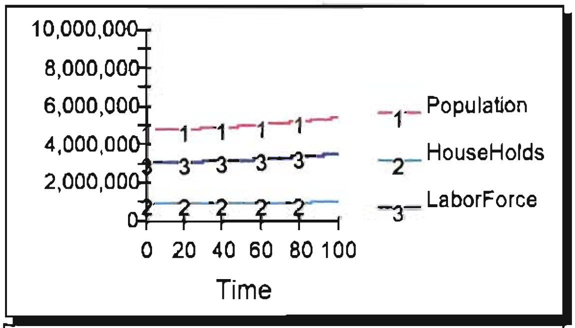

250,000
200,000
150,000
100,000
50,000
0
0 40 100
Time
1 FarmReclamationRate
2 FarmReclamationRate 2

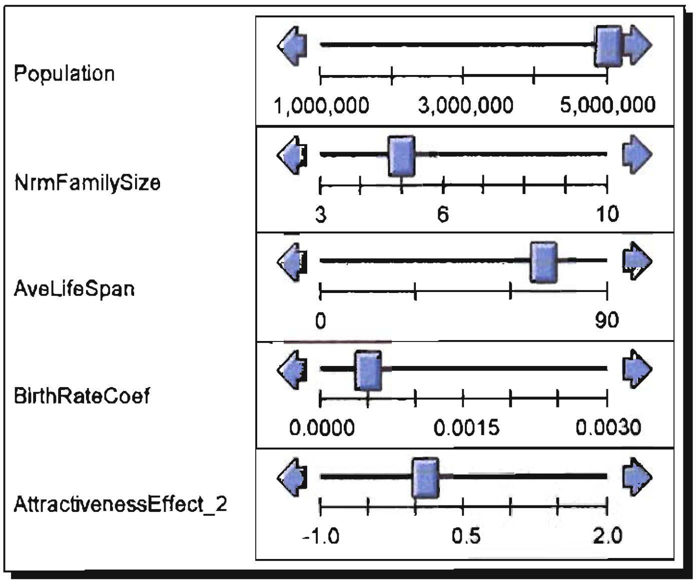
For this simulation, I wanted to study what would be the result if The Amazon region had planned communities, with a small population around 5 million, with a low birth rate. This type of a simulation is theoretically, very similar to the way of life for the regional tribes of native indians in Amazonia, though their population is much smaller. This "biodome" would have to be completely self-sufficient, so land depletion rates would have to be low. Theoretically, being directly related to land depletion, production rates for crops and cattle would have to be relatively low in comparison to normal production rates, in essence, subsistence production. Since the region would need to have a very low in- migration rate, so as to keep the population as close as possible to 5 million; the AttractivenessEffect_2 would have to be very low. Subsistence production would not require a very large labor force, especially since the land reclamation rates are assumed to be very high. This simulation, is the least realist of the three because it would be impossible for the government to restrict access to the Amazon region to in- migrating persons. The region is too large to be able to theoretically 'close it off' from the rest of the country. As we know from previous simulations, a greater population would directly cause greater environmental degradation, thusly, the only solution to this problem is sustainable development. The results for this simulation are as follows:

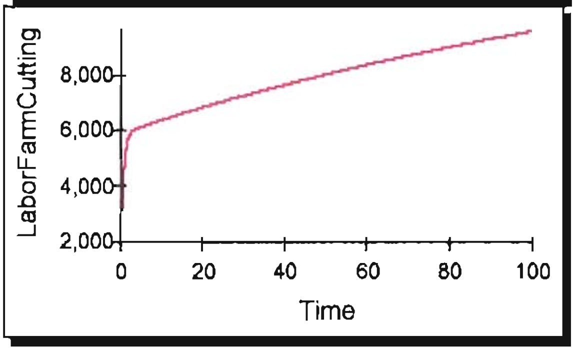
AMAZONIA AS A "BIO DOME" EXPERIMENT

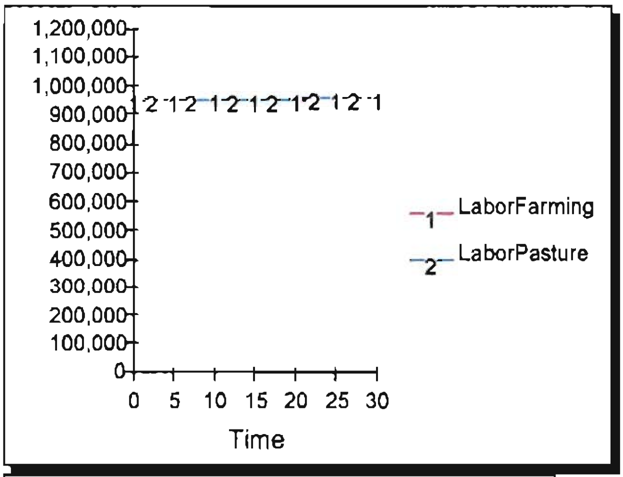
AMAZONIA MODEL CONTROL PANEL

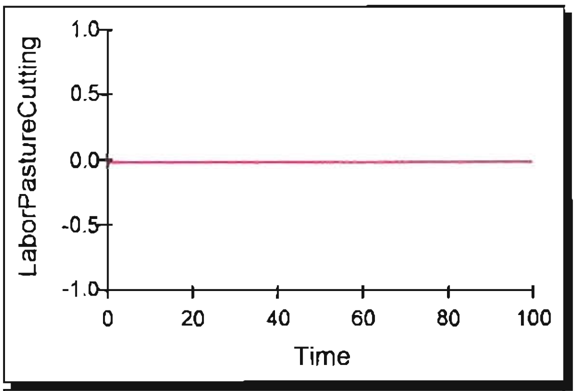
DEMOGRAPHIC SECTOR

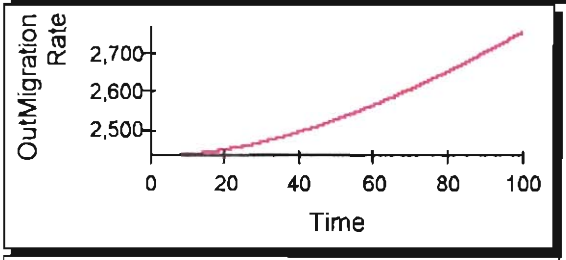


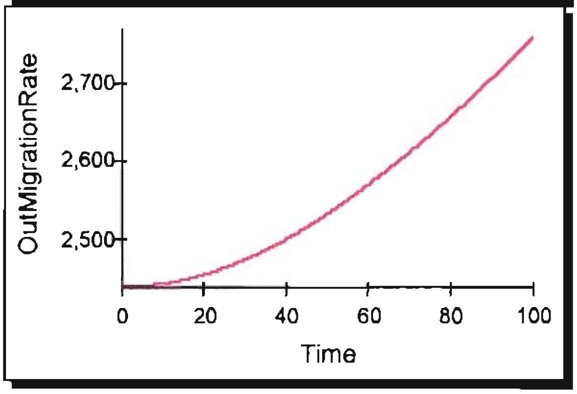


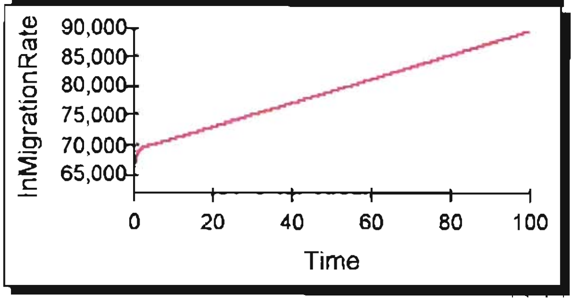




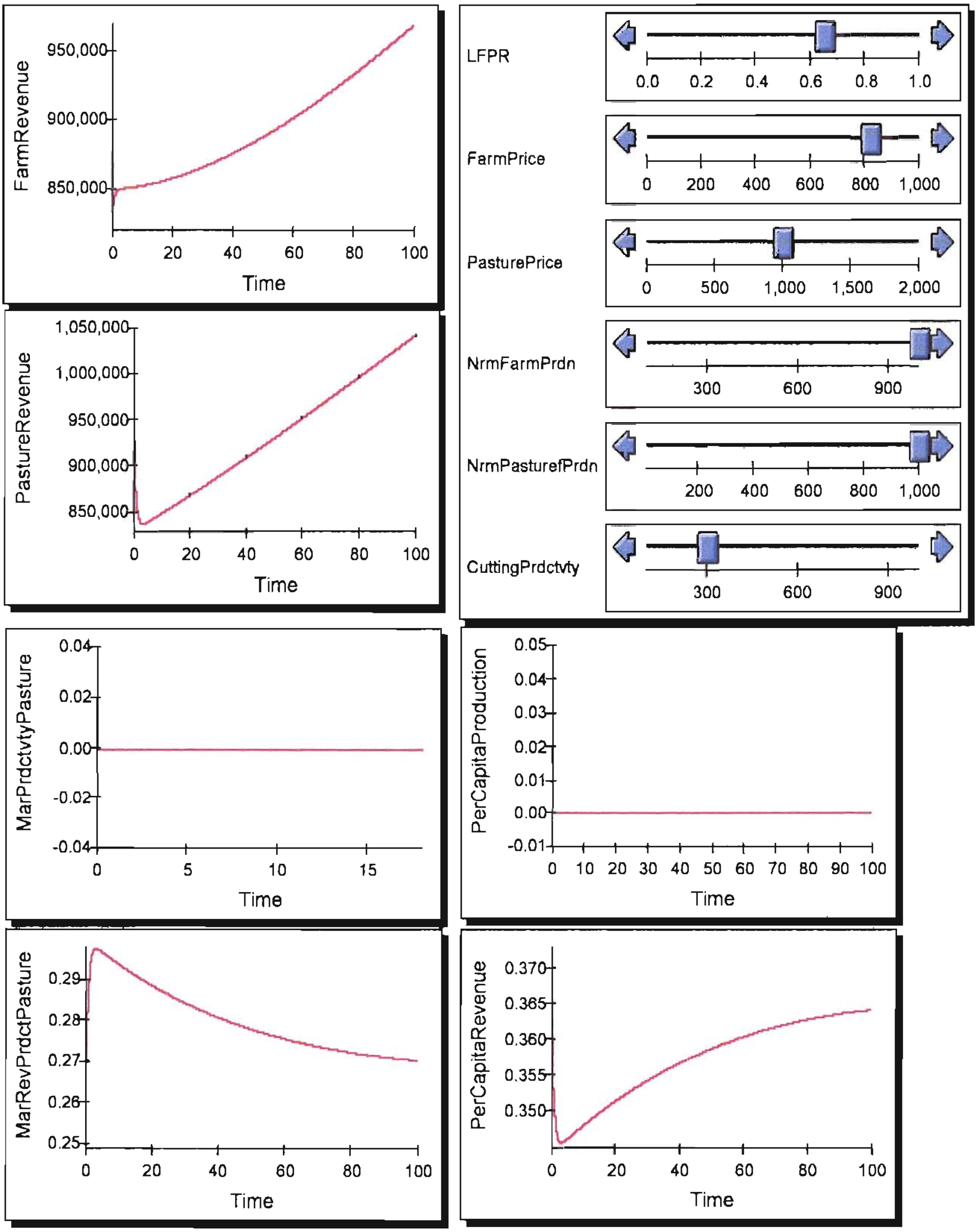


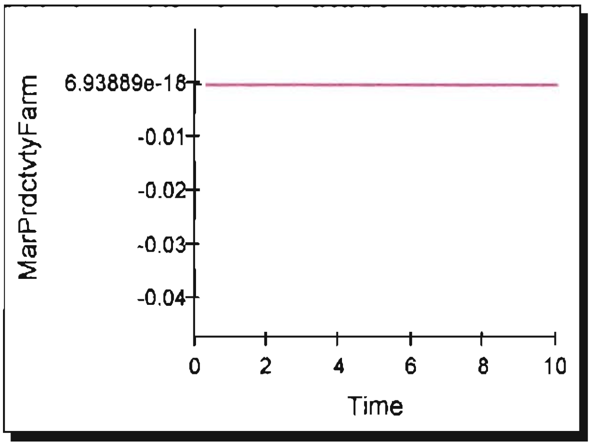




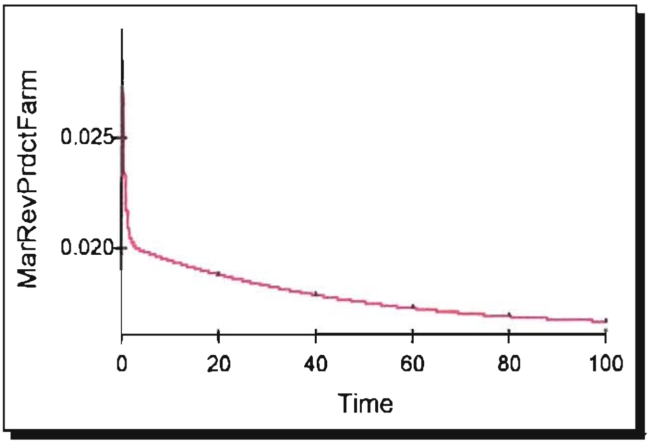


ECONOMIC SECTOR



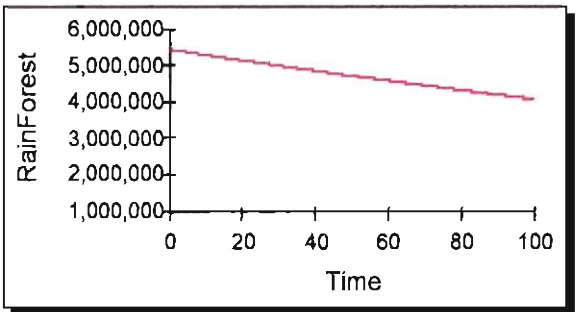


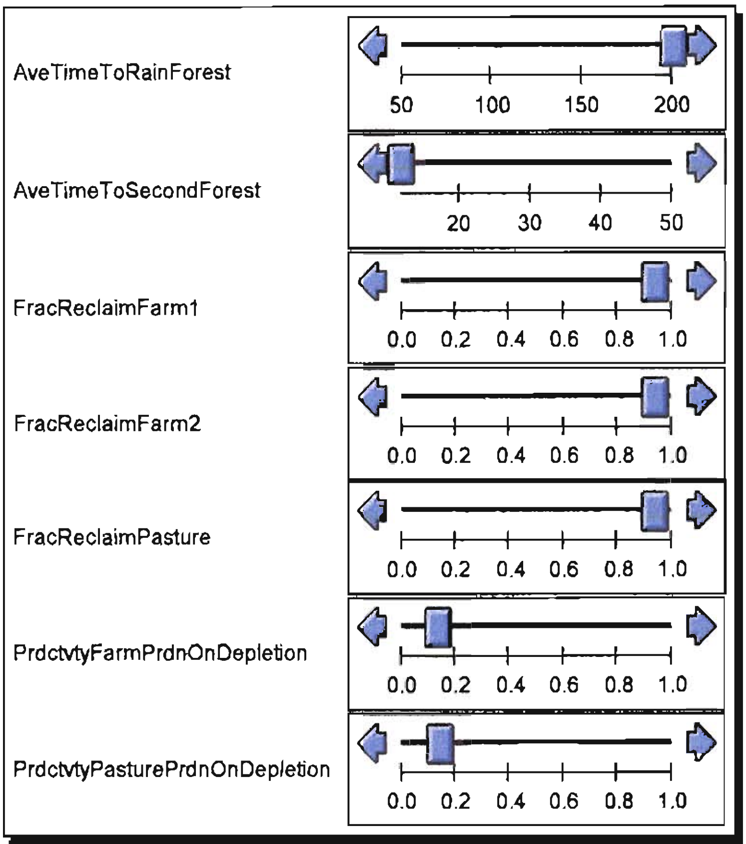
MarPrdctvtyFarm
6.93889e-18
-0.01
-0.02
-0.03
-0.04
0
2
4
6
8
10
Time

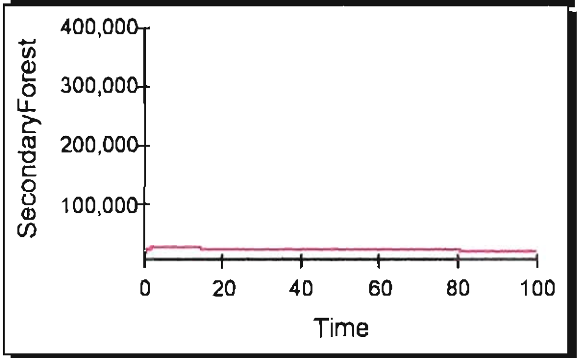


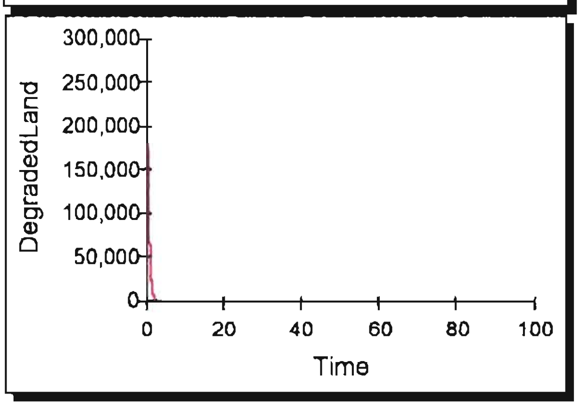
MarRevPrdctFarm
0.025
0.020
0
20
40
60
80
100
Time

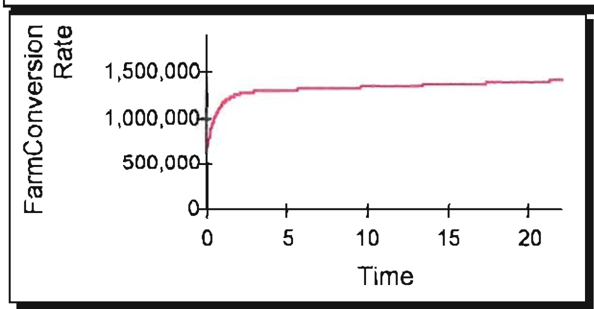
ENVIRONMENTAL SECTOR

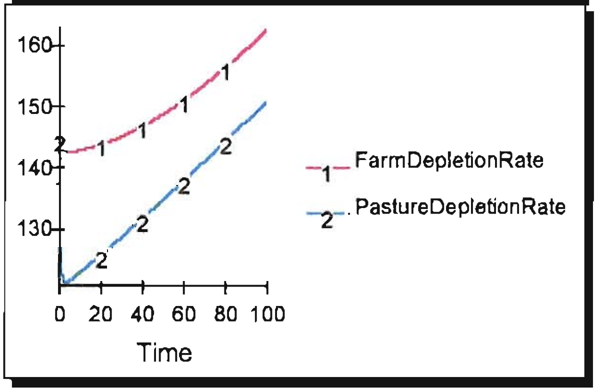


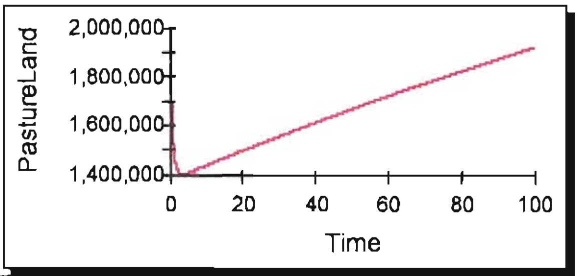


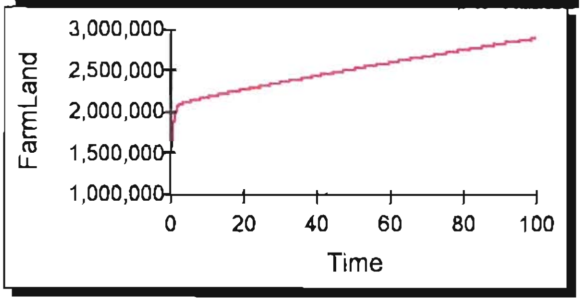


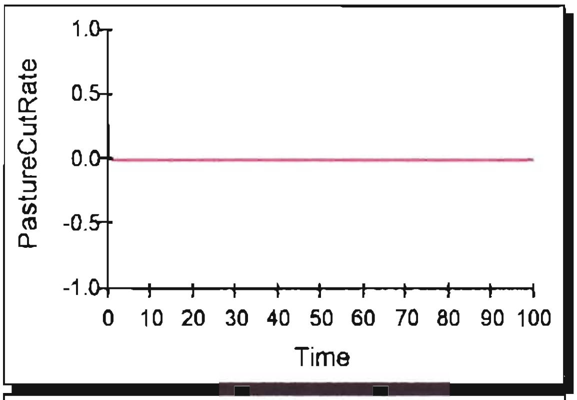


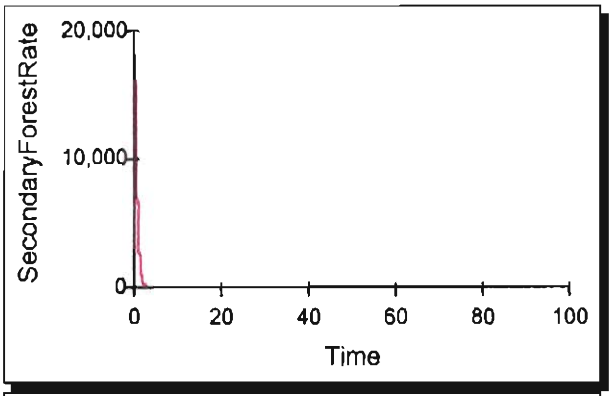


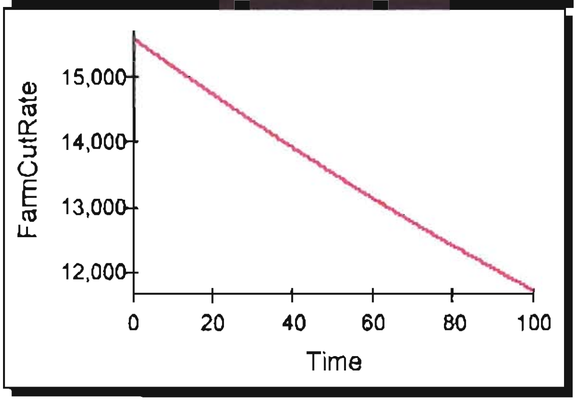


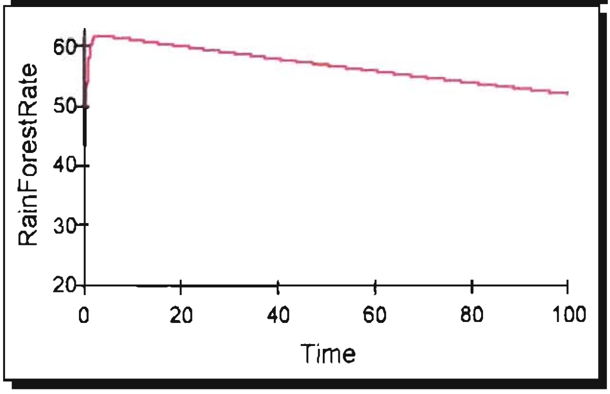


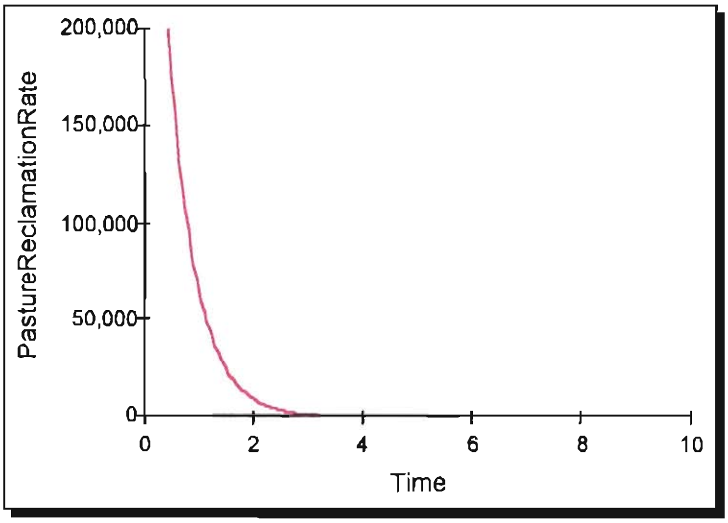


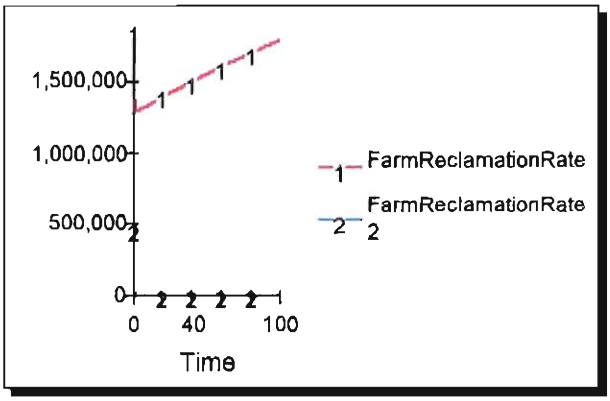

PastureCutRate
1.0
0.5
0.0
-0.5
-1.0
0 10 20 30 40 50 60 70 80 90 100
Time


SecondaryForestRate
20,000
10,000
0
0 20 40 60 80 100
Time


FarmCutRate
15,000
14,000
13,000
12,000
0 20 40 60 80 100
Time


RainForestRate
60
50
40
30
20
0 20 40 60 80 100
Time


PastureReclamationRate
200,000
150,000
100,000
50,000
0
0 2 4 6 8 10
Time


1,500,000
1,000,000
500,000
0
0 40 100
Time
FarmReclamationRate
FarmReclamationRate 2

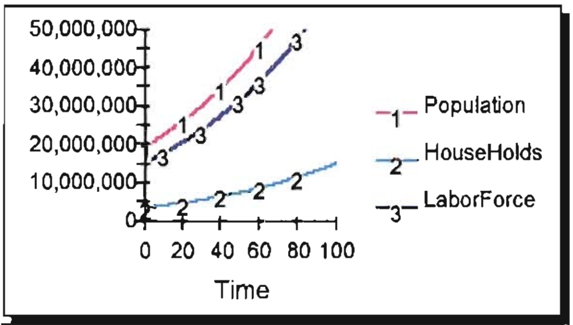
XII.IV.III Amazonia with a Relatively Sustainable Development

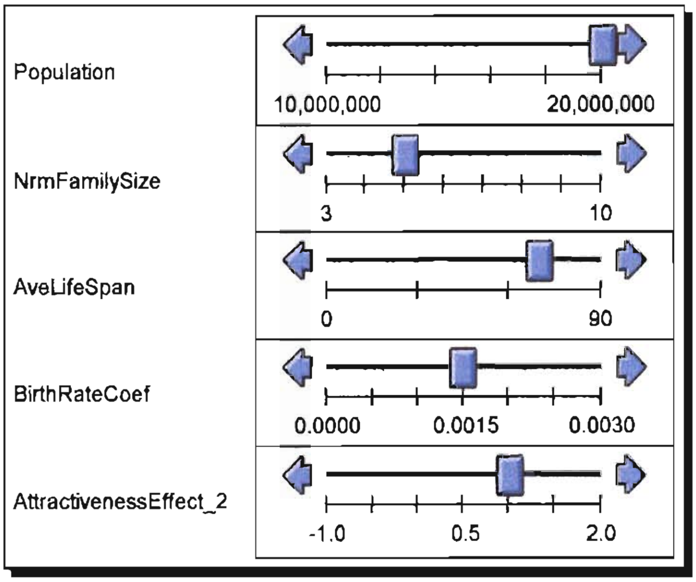
This simulation is based upon the following assumptions: the initial population should be moderately large so as to be a theoretically more realistic value, as opposed to being either too large, or too small, as was the case in the previous simulations. The initial population here was set to 12 million inhabitants. With relatively sustainable development, the reclamation rates for degrading land would be relatively high, or as was in the simulated case, around 80% reclamation of degrading land. Since the region would have a medium sized population, I assumed that the depletion of lands would be moderate. In addition, I set the labor force to 80% of the population, and a medium attractiveness effect. This simulation is in effect, an 'average' of the two previous ones because before I wished to see the simulation results at the extremes of population, population growth, and relative reclamation rates. The results of this simulation are as follows:

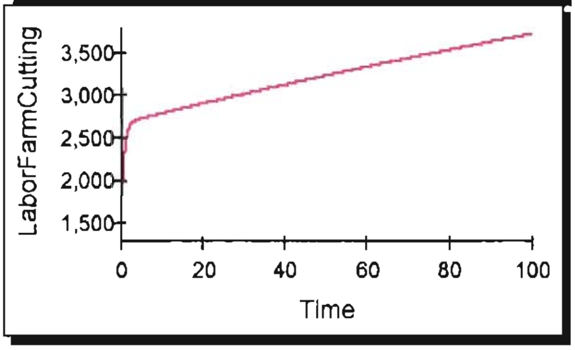
AMAZONIA WITH A RELATIVELY SUSTAINABLE DEVELOPMENT

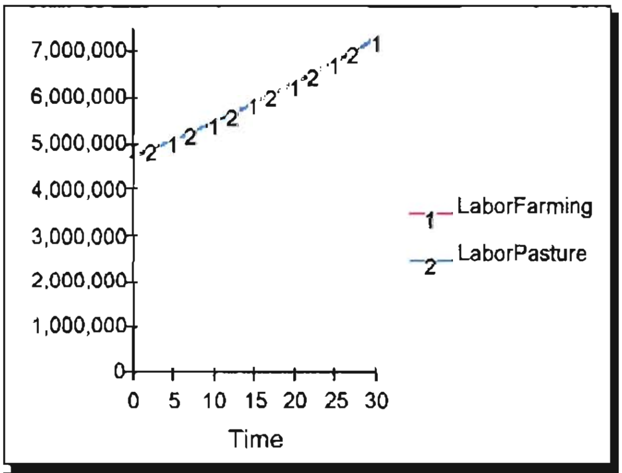
AMAZONIA MODEL CONTROL PANEL

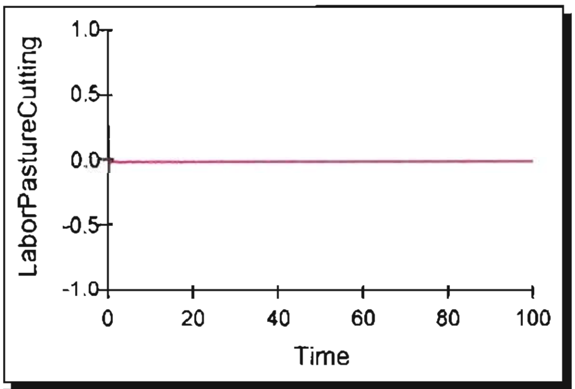
DEMOGRAPHIC SECTOR

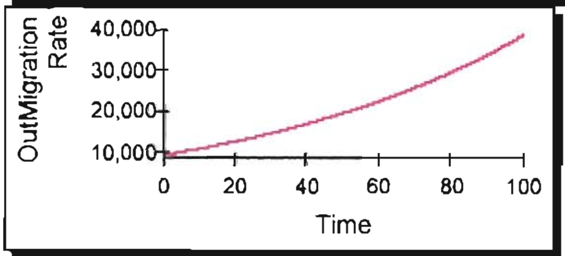


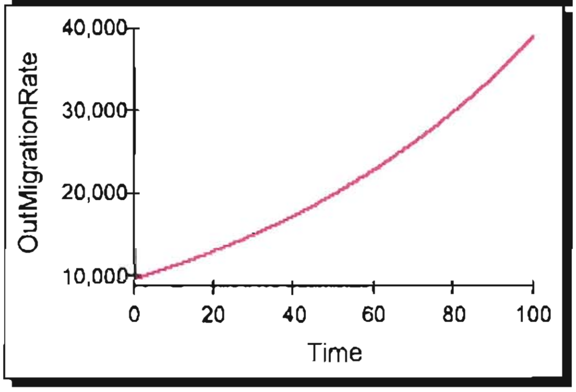


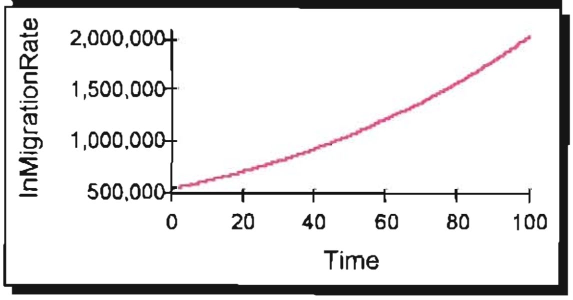




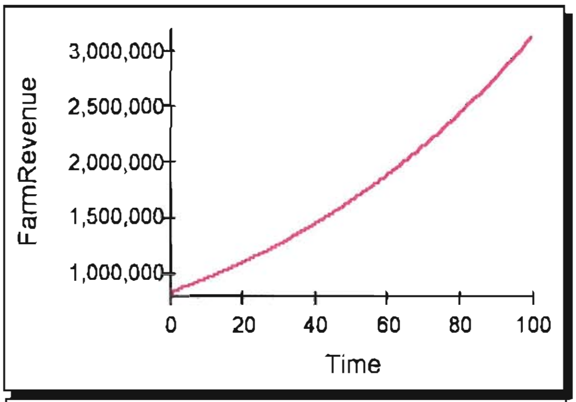


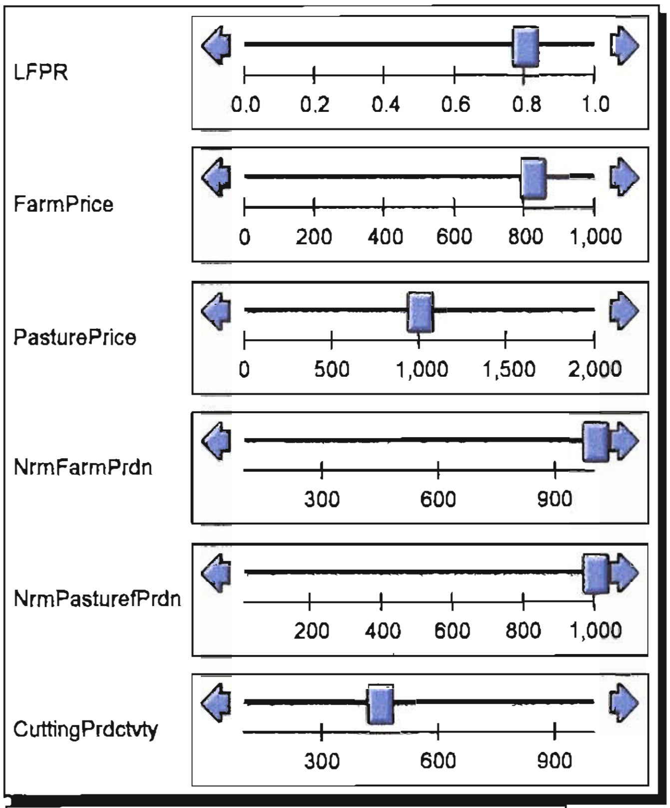


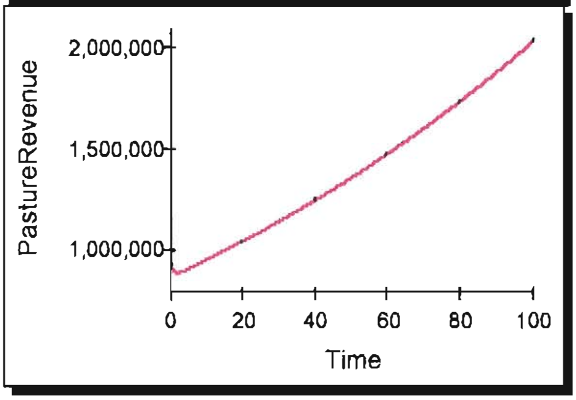


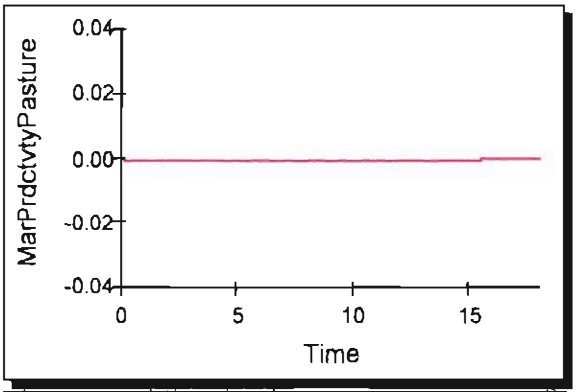


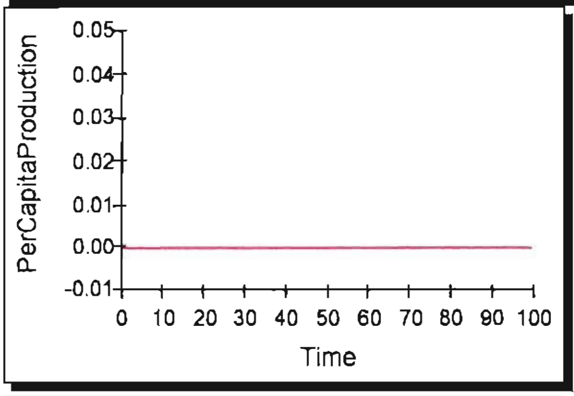
ECONOMIC SECTOR

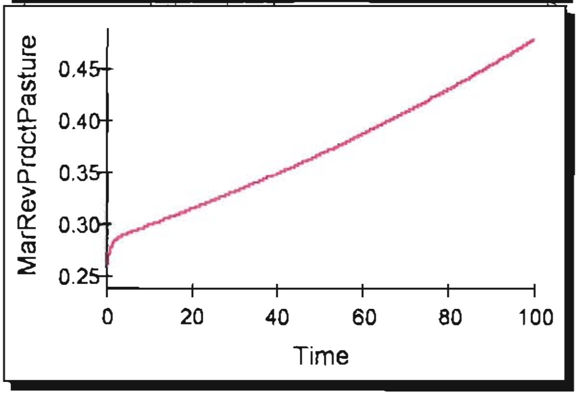


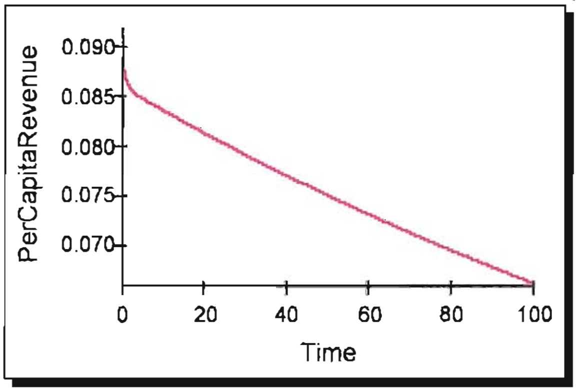


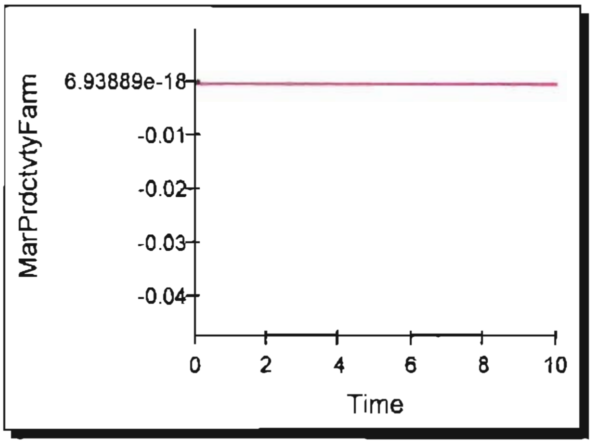




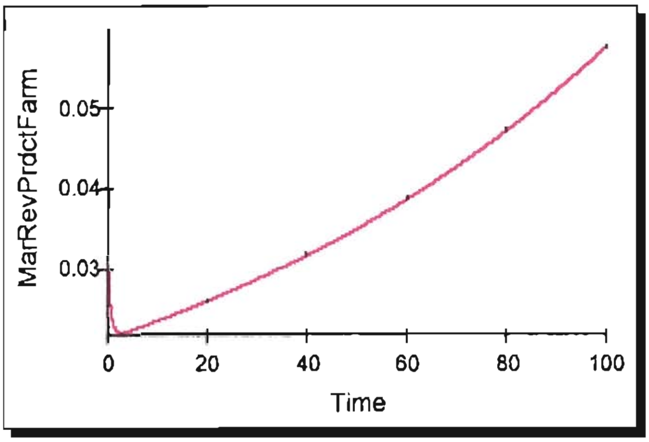






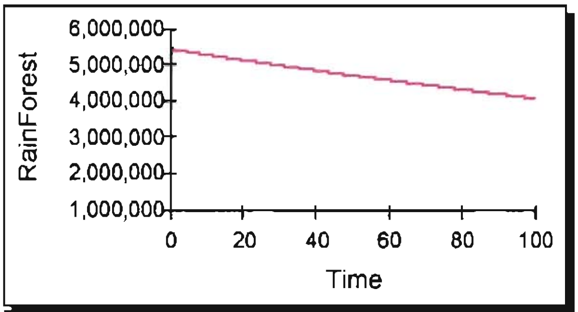


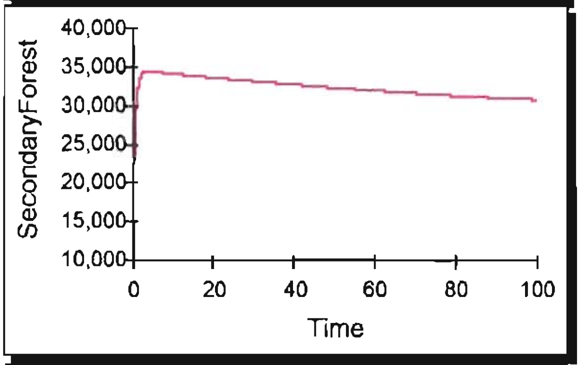
MarPrdctvtyFarm
6.93889e-18
-0.01
-0.02
-0.03
-0.04
0
2
4
6
8
10
Time

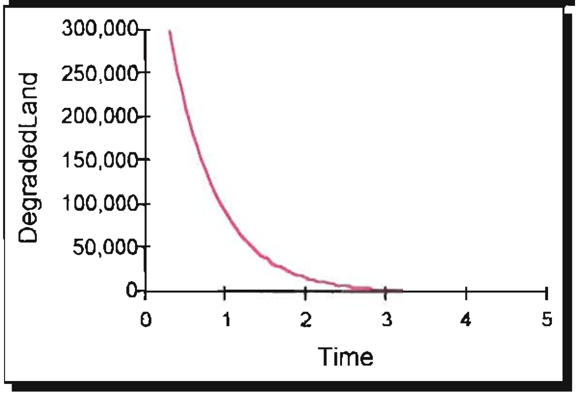


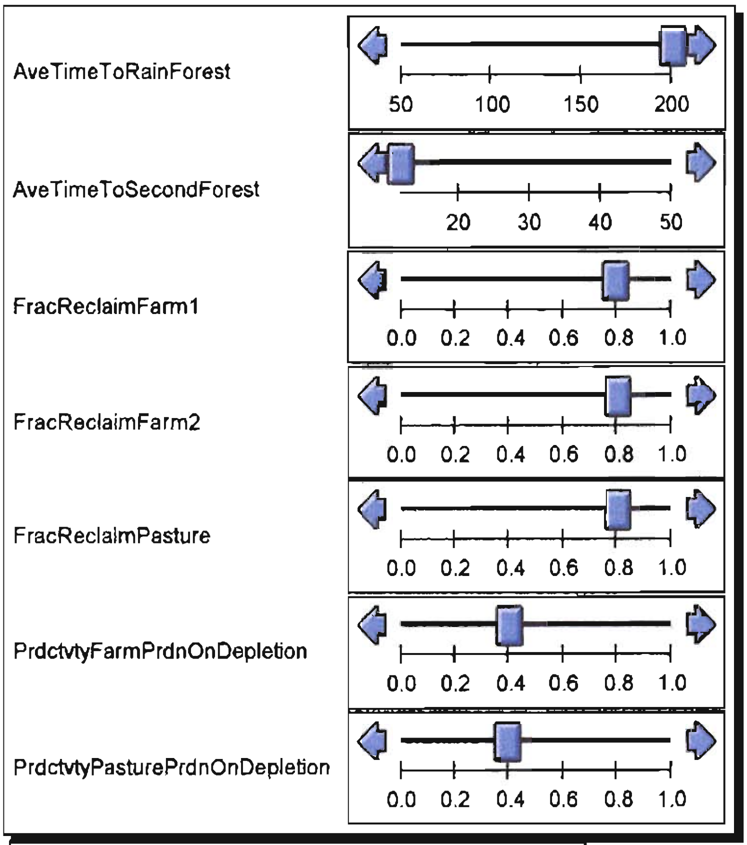
MarRevPrdctFarm
0.05
0.04
0.03
0
20
40
60
80
100
Time

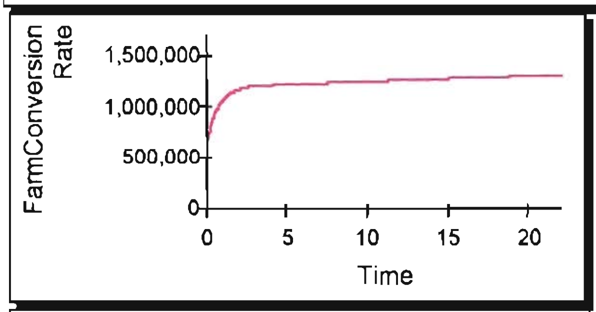
ENVIRONMENTAL SECTOR

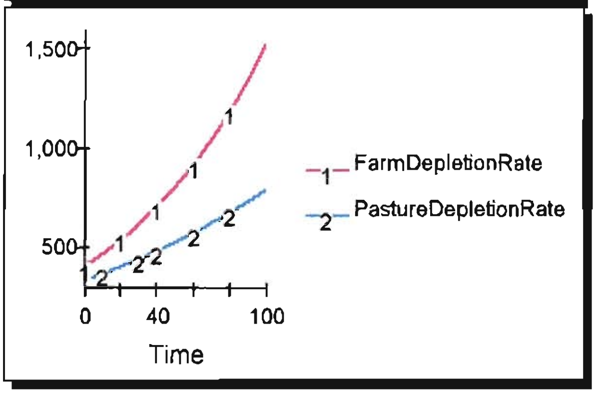


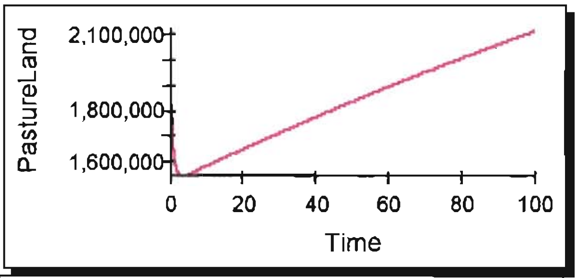


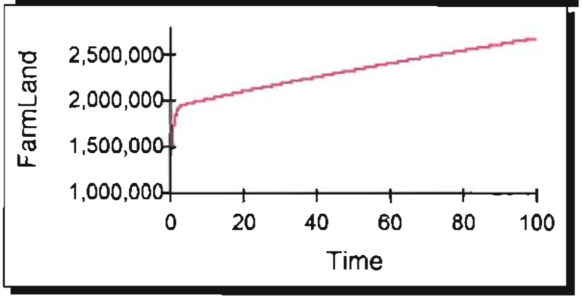


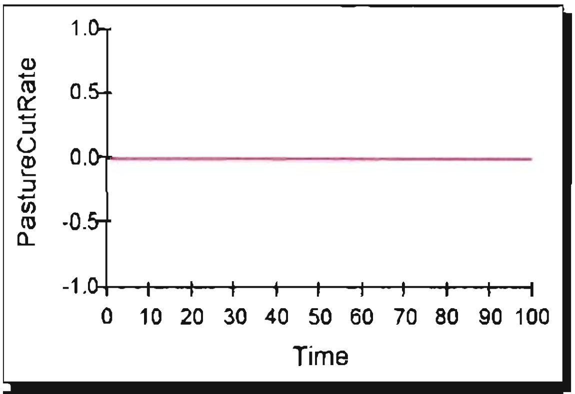


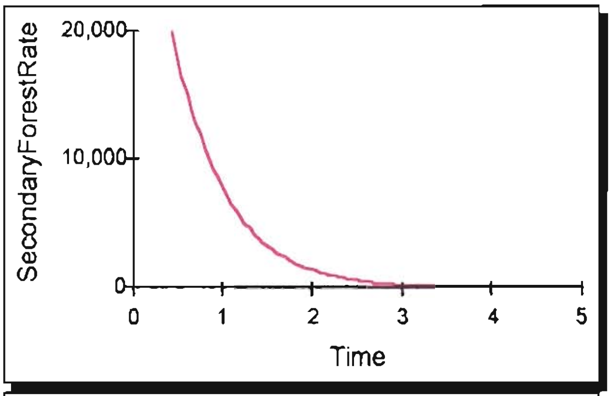


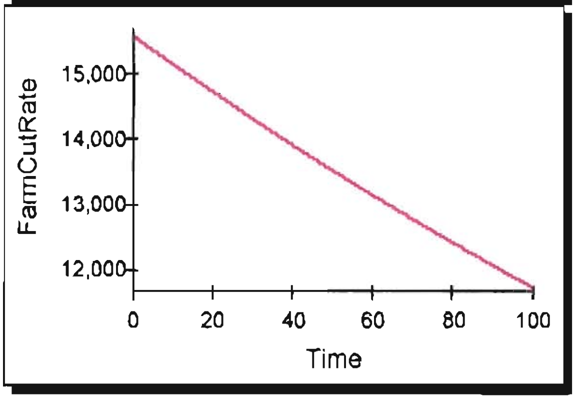


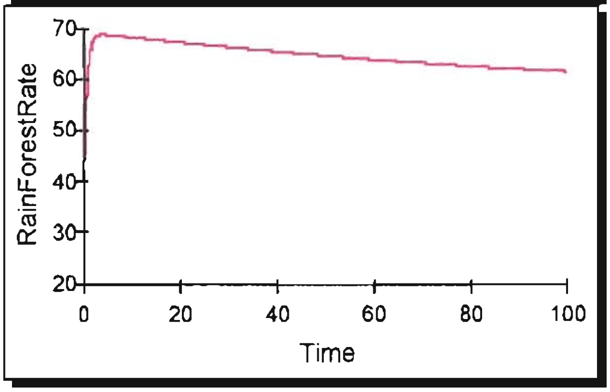


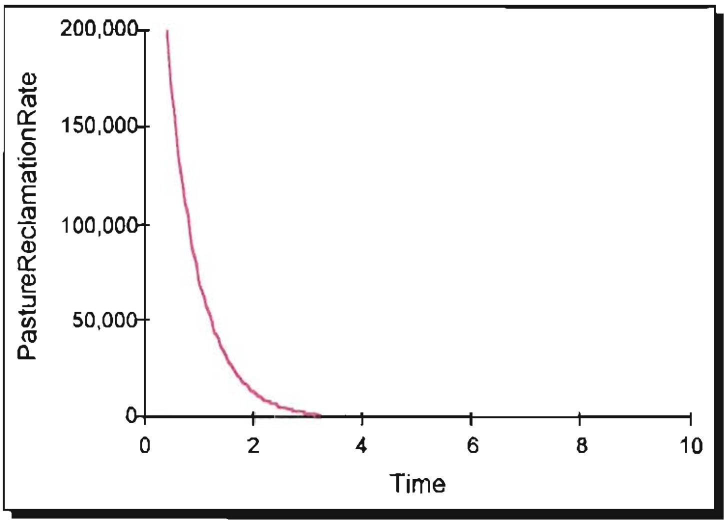


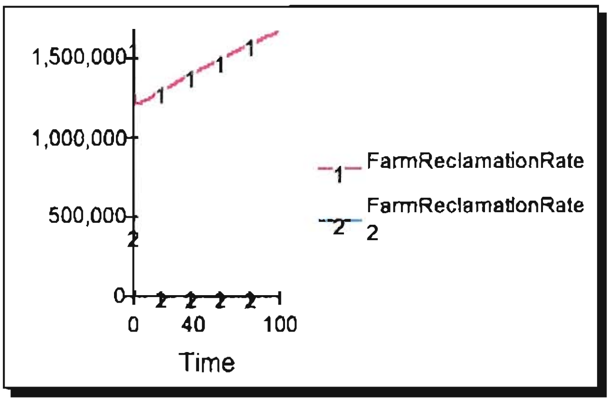

PastureCutRate
1.0
0.5
0.0
-0.5
-1.0
0 10 20 30 40 50 60 70 80 90 100
Time


SecondaryForestRate
20,000
10,000
0
0 1 2 3 4 5
Time


FarmCutRate
15,000
14,000
13,000
12,000
0 20 40 60 80 100
Time


RainForestRate
70
60
50
40
30
20
0 20 40 60 80 100
Time


PastureReclamationRate
200,000
150,000
100,000
50,000
0
0 2 4 6 8 10
Time


1,500,000
1,000,000
500,000
0
0 40 100
Time
FarmReclamationRate
FarmReclamationRate 2

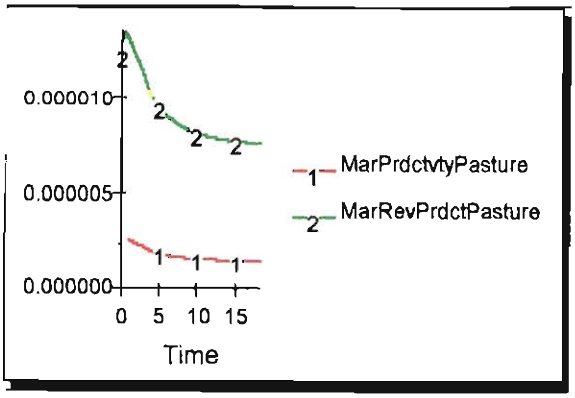
XII.IV.IV. Analysis and Conclusions from The Simulation Results

Several interesting relationships can be noted from the simulations.They are as follows:

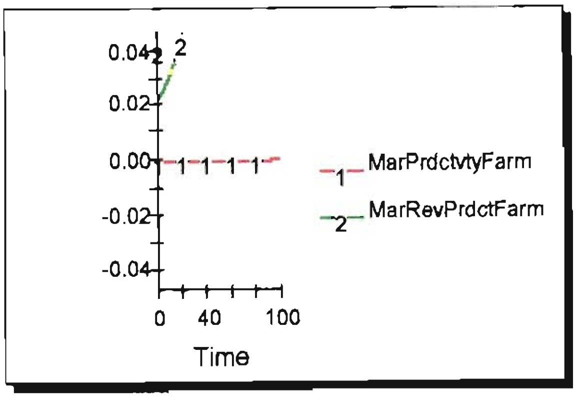
1.) As the region's population increases; the amount of labor that clears rainforest for farmland increases, as does the amount of labor that tends to crops and cattle (LaborFarming and LaborPasture, respectively), but the quantity of labor that clears rainforest for farmland always remains at zero. This happens because farmland naturally degrades into land that is suitable for raising cattle, so it would not be economically viable for the farmers to set a laborforce for preparing pasture land if they are already going to attain it through farmland degradation.

2.) As the region's population increases, farming and pasture revenues increase, but the rate of increase of both pasture and farming revenues increases slower than the rate of population growth; therefore, per capita revenues decrease.

3.) Marginal productivity calculations for cattle growing and farming result in zeros because by definition, the marginal productivity for a firm is equal to the percentage change in output, divided by the percentage change in inputs. Percentage changes in output here would consist as percentage changes in the normal pasture and farm production, but since they were set at specific constant values, no changes occurred. Previous simulations with variable pasture and farm production yielded the below results for marginal productivities. In the first case, the population over the fifteen year span was increasing, and therefore, the marginal productivity for pasture land increased until an optimum quantity of labor was reached. Thereafter, theoretically, the region would have too many laborers causing marginal productivities to fall. In the second case, the rising amount of labor in the region was increasing the amount of marginal revenues for regional farm production. Marginal farm revenues are increasing because the optimum quantity of labor in crop production in the Amazon region has not yet been reached.



CASE 1



CASE 2

4.) As the population increases, the farm and pasture land depletion rates increase; yet the farmland conversion rates decrease. This is explained through the increased attainment of pasture land caused by the increased depletion of farmland; therefore added pasture land would not need to be converted from farmland if nature already provides it.

5.) From the graphs of the stocks of rainforest in relation to time, it would be expected that with greater population and birth rates, increased quantities of rainforest would be cut down. Clearly, this is not the case with the simulated results. There is a trick here, the deceiving nature of dynamic systems...We must look at the above statement in detail. Ceteris paribus claims that the above statement is correct, and it would be in this case here, had the 'CuttingPrdctvty' constant remained unchanged through all three simulated runs. When the initial population was 50 million inhabitants, in addition to a high birth rate, the cutting productivity was set to be 1000 Hectares/Person/Year; in the next simulation, the initial population consisted of 5 million inhabitants, and there existed a very low birth rate, but the cutting productivity was set to 300 Hectares/Person/Year; and finally, in the final simulation, the initial population was set to 12 million, with a moderate birth rate, and a cutting productivity was set to 450 Hectares/Person/Year. Yes, the population and laborforce decreases with each simulation, respectively simulations 1,3,2, but the decreasing laborforces' efficiency in cutting rainforest increases. This is why the graphs are very similar.

XII.IV.V. Concluding Remarks and Recommendations

In conclusion, through the development of this project, The following were achieved:

1.) A complete and detailed historical account of the history of the Amazon region, showing in fact that the region has been connected to Brazil's economic structure ever since the time of the country's period as an empire;

2.) A complete description of the history of the social, environmental, and economic problems which have accompanied the Amazon region since it was integrated with the rest of the country, from the latter half of the twentieth century on to present times;

3.) The concepts of sustainable development and carrying capacity have been originally defined with a focus in the case of Amazonia;

4.) A detailed description of the characteristics of the Amazon Rainforest;

5.) A detailed analysis of some of the major misconceptions and myths about the Amazon region;

6.) An introduction into System Dynamics modeling techniques and its original application to the economic, social, and environmental structures of the Amazon region;

7.) The creation of an original model describing the transition of land usage in Amazonia, based on rational economic logic and demographic structures.

8.) The simulation of the Amazonia model, and the types of results obtained from the major variables involved in the model.

Sustainable development is not a difficult concept to understand, but it is a difficult concept to apply. Sustainability calls for reduced production of goods and services so that the "ends do not destroy the means." This is not a popular policy to employ anywhere in the world where economic development and ever greater profits are demanded, and environmental degradation goes hand in hand; nor would it be possible to employ. If anything has been learned at all in this project, it is that global sustainability is the key to human survival on this spaceship we call planet Earth, not just in Amazonia. All nations should come forward and take part in preserving the natural heritage that is all ours. I encourage the reader to draw their own conclusions from the information presented in this project, and listen to the warning signs that are all around us from our planet.

XIII. Bibliography

- Barrow, Chris. *Environmentally Approproprіate, Sustainable Small- Farm Strategies for Amazonia*. (article)
- Clarence Zuvekas, Jr., 1979. *Economic Development, An Introduction*, St. Martin's Press, Inc., New York, NY, USA.
- Commission on Development and Environment for Amazonia, *Amazonia Without Myths*, 1992. United Nations Headquarters, New York, NY, USA.
- Commission on Sustainable Development, Report on hte Fourth Session (18 April-3 May 1996) Economic and Social Council, Official Records, Supplement No.8, 1996. United Nations Headquarters, New York, NY, USA.
- Inter-American Development Bank, 1987. *Economic and Social Progress in Latin America*, Washington, DC, USA.
- De Araujo, Aloisio Barboza, 1979. *O Meio Ambiente no Brasil: Aspectos Economicos*, (The Environment in Brazil: Economic Aspects) IPEA/ INPES, Rio de Janeiro, RJ, Brazil.
- Dubois, Jean 1996. *Manual Agroflorestal para a Amazonia*, (Agroforestry Manual for Amazonia) Vol.1 REBRAF, Rio de Janeiro, RJ, Brazil.
- Economic Commission for Latin America and the Caribbean, 1986. *Peasant Agriculture in Latin America and The Caribbean*, Santiago de Chile
- Furley, Peter. *The Nature and Sustainability of Brazilian Amazon Soils*. (article)
- Goodman, David and Hall, Anthony, 1990. *The Future of Amazonia: Destroction, or Sustainable Development?*, Basingstoke, England
- Hall, Anthony, 1997. *Sustaining Amazonia: Grassroots Action for Productive Conservation*, Manchester, England.
- IBGE (Brazilian Institute of Geography and Statistics), 1992. *Brazil in Figures* Vol.1, Rio de Janeiro, RJ, Brazil.

- Interministerial Commission for the Preparation of the United Nations Conference on Environment and Development, 1992. _The Challenge of Sustainable Development._ The Brazilian report for the United Nations conference on Environment and development, Brasilia, D.F., 1992.
- IPEA (Institute of Economic and Social Planing), 1975. _Brazilian Economic Studies_ (book 1) IPEA/ INPES, Rio de Janeiro, RJ, Brazil.
- IPEA (Institute of Economic and Social Planing), 1976. _Brazilian Economic Studies_ (book 2) IPEA/ INPES, Rio de Janeiro, RJ, Brazil.
- IPEA (Institute of Economic and Social Planing), 1984. _Brazilian Economic Studies_ (book 8) IPEA/ INPES, Rio de Janeiro, RJ, Brazil.
- Pearce, David and Myers, Norman. _Economic Values and The Environment of Amazonia._ (article)
- Tavares, Vania Porto, 1972. _Colonizacao Dirigida no Brasil,_ (Incentivized Colonization in Brazil) IPEA/ INPES; Rio de Janeiro, RJ, Brazil.
- Todaro, Michael P., 1997. _Economic Development,_ USA
- United Nations, 3-14 June 1992. _Report of the United Nations Conference on Environment and Development,_ Vol. 1 Rio de Janeiro, RJ, Brazil
- United Nations, Economic and Social Council, 11-28 April 1995. Commission on Sustainable Development, Third Session. _Poverty Eradication and Sustainable Development,_ Report of the Secretary General. United Nations Headquarters, New York, NY, USA.
- United Nations, Economic and Social Council, 11-28 April 1995. Commission on Sustainable Development, Third Session. _Promoting Sustainable Agriculture and Rural Development,_ Report of the Secretary General. United Nations Headquarters, New York, NY, USA.
- United Nations, Economic and Social Council, 11-28 April 1995. Commission on Sustainable Development, Third Session. _Demographic Dynamics and Sustainability,_ Report of the Secretary General. United Nations Headquarters, New York, NY, USA.

- United Nations, Economic and Social Council, 11-28 April 1995. Commission on Sustainable Development, Third Session. *Transfer of Environmentally Sound Technologies, Cooperation and Capacity Building*, Report of the Secretary General. United Nations Headquarters, New York, NY, USA.
- United Nations, Economic and Social Council, 11-28 April 1995. Commission on Sustainable Development, Third Session. *Conservation of Biological Diversity*, Report of the Secretary General. United Nations Headquarters, New York, NY, USA.
- United Nations, Economic and Social Council, 11-28 April 1995. Commission on Sustainable Development, Third Session. *Changing Consumption and Production Patterns*, Report of the Secretary General. United Nations Headquarters, New York, NY, USA.
- United Nations, Economic and Social Council, 18 April 3 May 1996. Commission on Sustainable Development, Fourth Session. *Changing Consumption and Production Patterns*, Report of the Secretary General. United Nations Headquarters, New York, NY, USA.
- United Nations, 1994. *World Economic and Social Survey*, United Nations, NY, USA.
- United Nations, 1996. *World Economic and Social Survey*, United Nations, NY, USA.
- United Nations, 1998. *World Economic and Social Survey*, United Nations, NY, USA.
- United Nations, June 1996. *World Resources: A Guide to the Global Environment*, Habitat II, The United Nations Conference on Human Settlements, World Resorces, New York, NY, USA.

Web Page Addresses:

- http://www.inpe.br
- http://www.ibge.gov.org
- http://www.ibge.gov.br
- http://www.mma.gov.br
- http://www.sudam.gov.br

XIV. Annex

Extensão do Desflorestamento Bruto (km²)

EXTENT OF DEFORESTATION (ACCUMULATED)

ESTADOS	Jan/78	Abr/88	Ago/89	Ago/90	Ago/91	Ago/92	Ago/94	Ago/95	Ago/96
ACRE	2500	8900	9800	10300	10700	11100	12064	13306	13742
AMAPA	200	800	1000	1300	1700	1736	1736	1782	1782
AMAZONAS	1700	19700	21700	22200	23200	23999	24739	26629	27434
MARANHAO	63900	90800	92300	93400	94100	95235	95979	97761	99338
MATO GROSSO	20000	71500	79600	83600	86500	91174	103614	112150	119141
PARA	56400	131500	139300	144200	148000	151787	160355	169007	176138
RONDONIA	4200	30000	31800	33500	34600	36865	42055	46152	48648
RORAIMA	100	2700	3600	3800	4200	4481	4961	5124	5361
TOCANTINS	3200	21600	22300	22900	23400	23809	24475	25142	25483
AMAZONIA LEGAL	152200	377500	401400	415200	426400	440186	469978	497055	517069

Taxa Média de Desflorestamento Bruto (km²/ano)

ANNUAL DEFORESTATION FIGURES

Media decada Bienio 92/94	78/88*	88/89	89/90	90/91	91/92	92/94**	94/95	95/96
ACRE	620	540	550	380	400	482	1208	433
AMAPA	60	130	250	410	36	—	9	
AMAZONAS	1510	1180	520	980	799	370	2114	1023
MARANHAO	2450	1420	1100	670	1135	372	1745	1061
MATO GROSSO	5140	5960	4020	2840	4674	6220	10391	6543
PARA	6990	5750	4890	3780	3787	4284	7845	6135
RONDONIA	2340	1430	1670	1110	2265	2595	4730	2432
RORAIMA	290	630	150	420	281	240	220	214
TOCANTINS	1650	730	580	440	409	333	797	320
AMAZONIA LEGAL	21130	17860	13810	11130	13786	14896	29059	18161

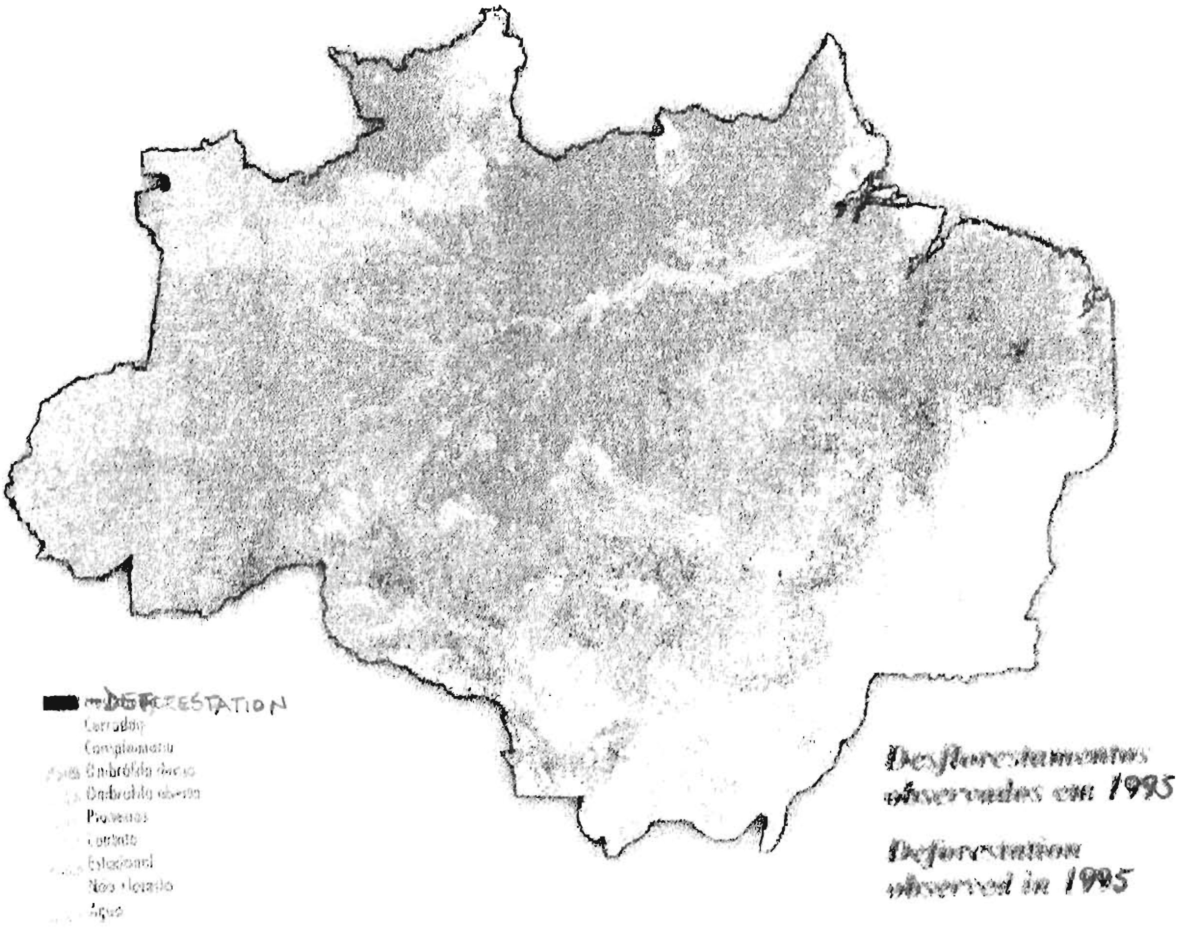
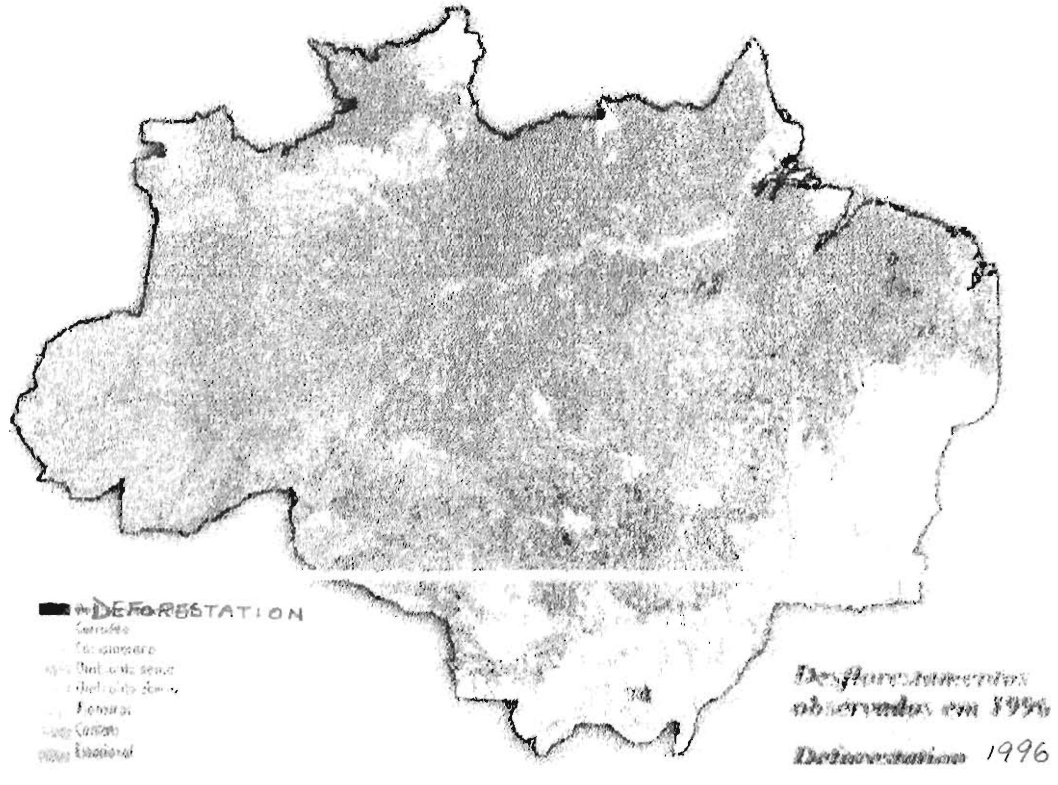

DEFORESTATION
Desflorestamentos observados em 1995
Deforestation observed in 1995

Fig. 4


DEFORESTATION
Desflorestamentos observados em 1996
Deforestation 1996

2. Classificação dos SAFs

Existem muitas classificações dos SAFs e todas têm suas falhas. Por outro lado, para quem trabalha no campo, um conhecimento detalhado das classificações é dispensável. O assunto interessa mais aos profissionais de formação universitária.

No final deste volume (ver **Anotações**), os interessados encontrarão mais informações a respeito[1]. Aqui será apresentada uma classificação simplificada, abrangendo apenas as três categorias principais:

Sistemas silvi-agrícolas, caracterizados pela combinação de árvores ou arbustos com espécies agrícolas (**Figura 1.2**). Exemplos: consórcios agroflorestais simples do tipo café-freijó ou, mais complexas, como pupunha / cupuaçu /castanheira-do-brasil / mogno.

REFER TO THE PICTURES:

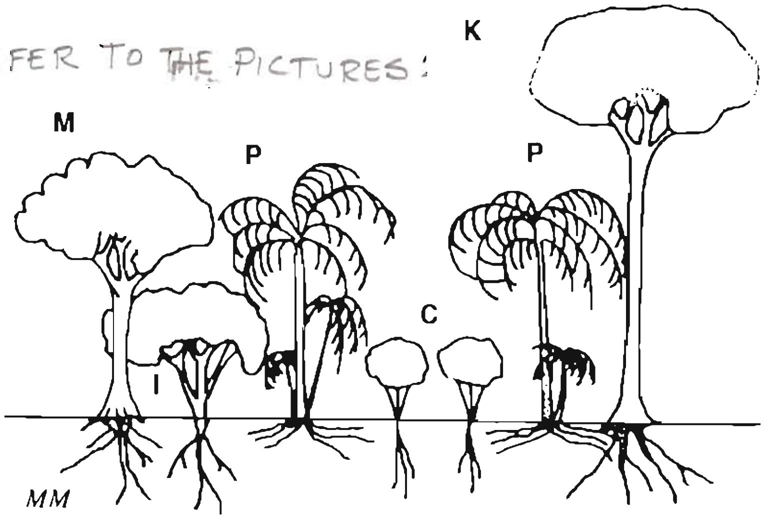


Figura 1.2

SIVI-AGRICUTURAL AGROFORESTRY SYSTEM (AFS)

Sistema silvi-agrícola

P = pupunha
C = cupuaçu
K = castanheira-do-brasil
M = mogno
I = ingá-cipó

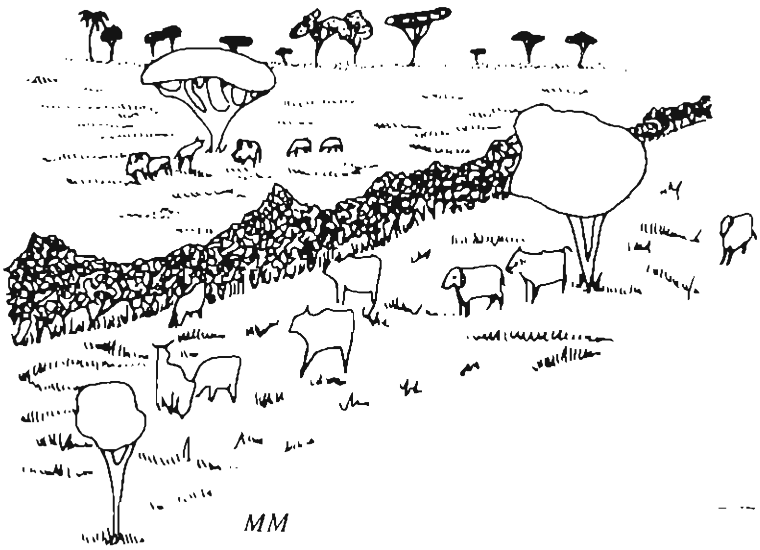
Sistemas silvipastoris, caracterizados pela combinação de árvores ou arbustos com plantas forrageiras herbáceas e animais (**Figura 1.3**). Exemplo: a combinação de pasto com castanheira-do-brasil.

Figura 1.3

SILVI-PASTURAL AFS

Sistema silvipastoril

Uso de faixas divisórias constituídas por espécies arbustivas forrageiras



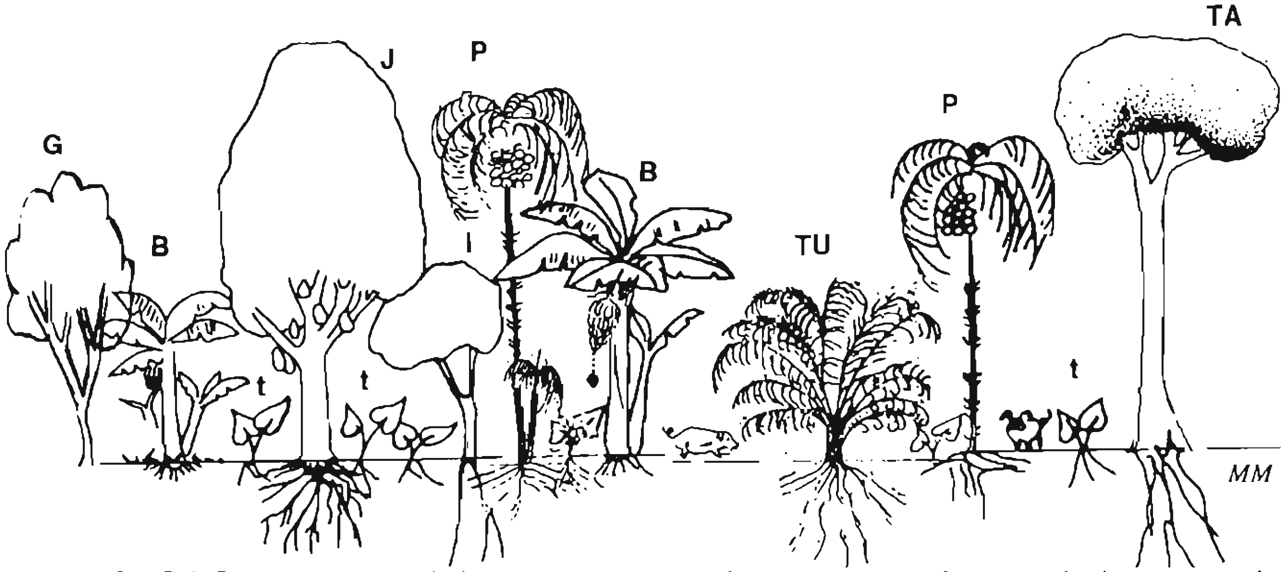
Sistemas agrossilvipastoris, caracterizados pela criação ou manejo de animais em consórcios silvi-agrícolas (**Figura 1.4**). Exemplos: agrofloresta para criação de porcos; um quintal com fruteiras, hortaliças e galinhas.

Figura 1.4

AGRO-SILVI - PASTURAL AFS FOR RAISING PIGS.

Sistema agrossilvipastoril: uma agrofloresta para porcos

B-	bananeira	G-	goiabeira	I-	ingá-cipó	J-	jaqueira
P-	pupunheira	t-	taioba	TU-	tucumã	TA-	tatajuba



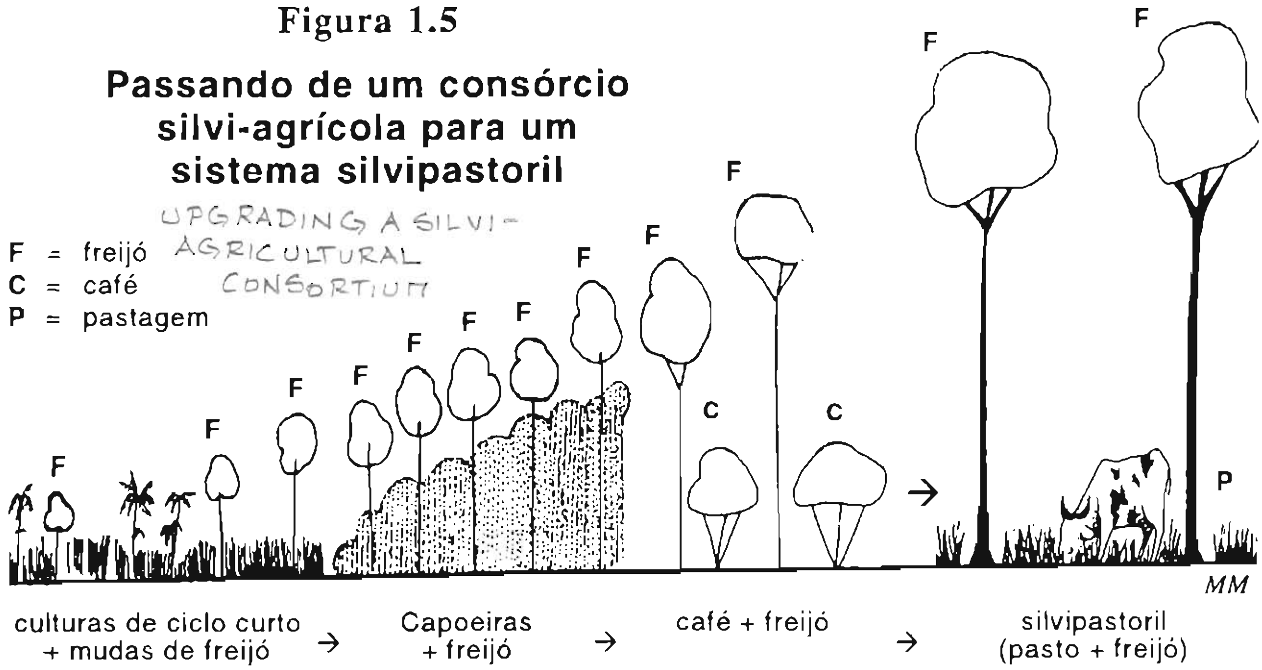
Os SAFs podem evoluir, com o passar do tempo, em função do interesse do agricultor. Por exemplo, um agricultor plantou, numa lavoura branca, café e alguns pés de ingá-cipó e de freijó. Essa combinação pertence à categoria de sistemas silvi-agrícolas. Depois de mais ou menos 10 anos o café, cuja produção caiu muito, foi arrancado e substituído por pasto. Dessa maneira, a combinação se transformou em sistema silvipastoril (**Figura 1.5**).

Figura 1.5

Passando de um consórcio silvi-agrícola para um sistema silvipastoril

UPGRADING A SILVI-AGRICULTURAL CONSORTIUM

F = freijó
C = café
P = pastagem



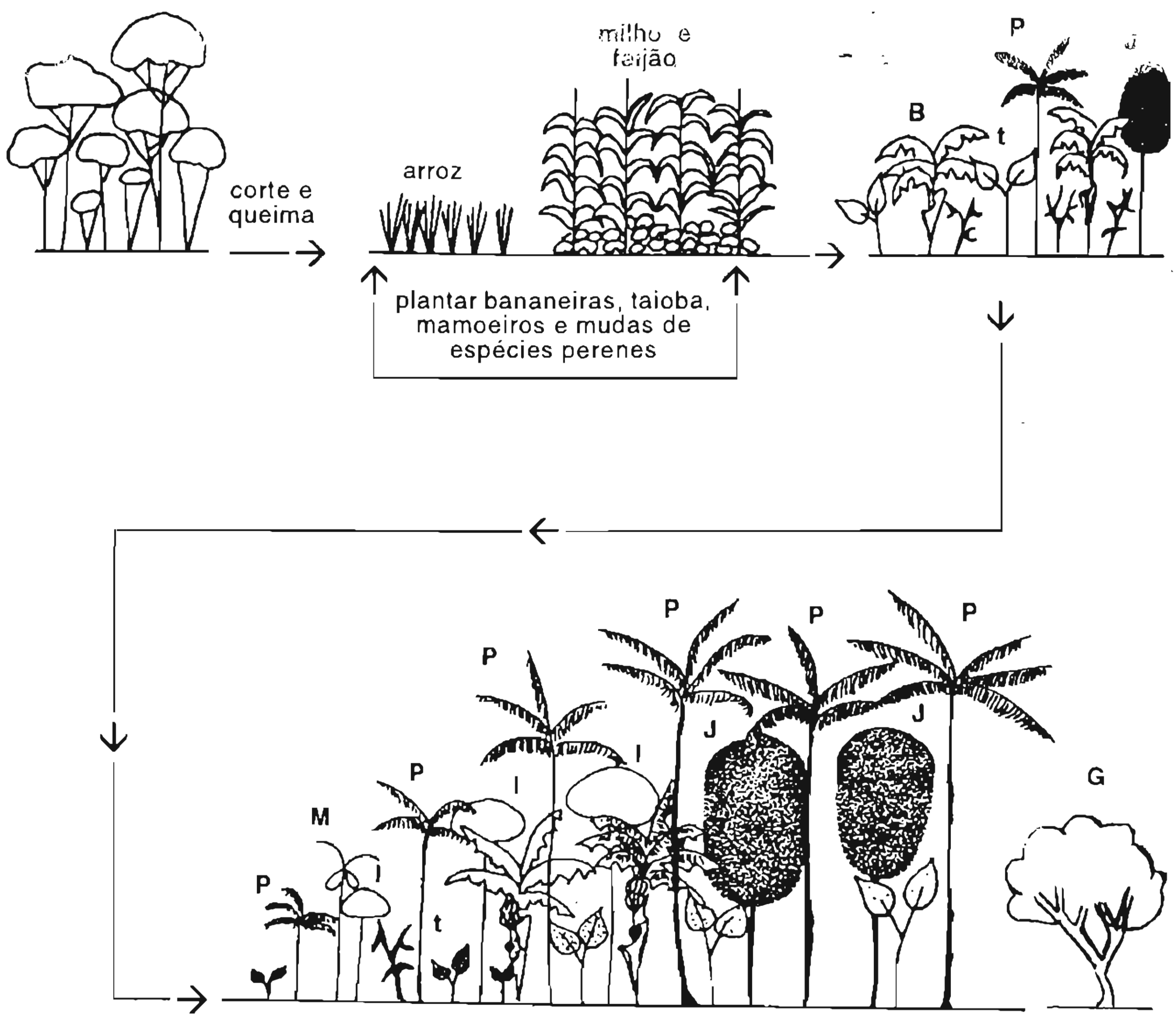
Porém, na maioria dos casos, a implantação desses sistemas pode ser feita de forma progressiva, dividindo-se o trabalho em etapas sucessivas, repartidas sobre um período relativamente longo de tempo (de três a cinco anos). Isso acontece, por exemplo, na implantação progressiva de uma agrofloresta de uso múltiplo, a partir de um roçado de lavoura branca (**Figura 1.10**).

Figura 1.10

Formação progressiva de uma agrofloresta para porcos.

PROGRESSIVE FORMATION OF AN AFS FOR PIGS

B- bananeira **G**- goiabeira **I**- ingá-cipó **J**- jaqueira **M**- mamoeiro
P- palmeiras (pupunha, tucumã...) **T**- taioba



AGROFLORESTA PARA PORCOS

EQUATIONS USED IN MODELING

☐ DegradedLand
INIT .5e6
-dt*FarmReclamationRate2
-dt*SecondaryForestRate
-dt*PastureReclamationRate
+dt*PastureDepletionRate

☐ FarmLand
INIT (1e6)
-dt*FarmDepletionRate
+dt*FarmReclamationRate
+dt*FarmReclamationRate2
-dt*FarmConversionRate
+dt*FarmCutRate

☐ FractLaborFarm
INIT .3
+dt*FarmLaborFracRate

☐ FractLaborPasture
INIT .3
+dt*PastLaborFracRate

☐ PastureLand
INIT 2e6
+dt*FarmDepletionRate
-dt*FarmReclamationRate
+dt*PastureReclamationRate
+dt*FarmConversionRate
+dt*PastureCutRate
-dt*PastureDepletionRate

☐ PERRERETURNTOPASTLAND
INIT 1
+dt*CHGPRERELRTRNPASTLAND

☐ Population
INIT 5e6
+dt*InMigrationRate
-dt*OutMigrationRate
-dt*DeathRate
+dt*BirthRate

☐ RainForest
INIT 5.5e6
+dt*RainForestRate
-dt*FarmCutRate
-dt*PastureCutRate

☐ SecondaryForest
INIT .01e6
+dt*SecondaryForestRate
-dt*RainForestRate

BirthRate
= Population*BirthRateCoef

CHGPRERELRTRNPASTLAND
= (MARGINALREVPASTFARMRATIO-PERRERETURNTOPASTLAND)/(TIMEPERRELRTRNPASTLAND+.0001)
(RELRETUNTOLAND-PERRERETURNTOLAND)/TIMEPERRELRTRNLAND

DeathRate
= Population/AveLifeSpan

FarmConversionRate
= (DesFarmConversionRate*EffCovFarmConvRate)

FarmCutRate
= IndFarmCutRate*EffRFCovFarmCutRate

FarmDepletionRate
= (EFFFLDEPLRATE*IndFarmDepletionRate)

FarmLaborFracRate
= (IndFracLaborFarm-FractLaborFarm)/FarmLaborAdjustTime

FarmReclamationRate
= PastureLand*FracReclaimFarm1

FarmReclamationRate2
= DegradedLand*FracReclaimFarm2
InMigrationRate
= Population*InMigrFrac
OutMigrationRate
= Population*OutMigrFrac
PastLaborFracRate
= (IndFracLaborPasture-FractLaborPasture)/PastLaborAdjstmentTime
PastureCutRate
= EffRFCovPastureCutRate*IndPastureCutRate
PastureDepletionRate
= EFFPASTCOV*IndPastureDepletionRate
PastureReclamationRate
= DegradedLand*FracReclaimPasture
RainForestRate
= SecondaryForest/AveTimeToRainForest
SecondaryForestRate
= DegradedLand/AveTimeToSecondForest
AttractivenessEffect_1
= GRAPH(HectareRatio,0,0.1,[0,0.24,0.45,0.61,0.73,0.8,0.86,0.92,0.96,0.99,1"Min:0;Max:1;Zoom"])
CorrforFarmLand
= MAX(0,(FarmLand-DesFarmLand)/TimeCorrFarmLand)
CorrforPastureLand
= MAX(0,(PastureLand-DesPastureLand)/TimeCorrPastureLand)
CorrPastureLandSL
= ((PastureDepletionRate*(1/PrdctvtyFarmPrdnOnDepletion))-FarmLand)/TimeCorrPastureLandSL
DesFarmConversionRate
= MAX(DesPastureLandAcquisitionRate,PotentialFarmConversionRate)
DesFarmCutRate
= MAX(0,FarmDepletionRate+FarmConversionRate+CorrforFarmLand)
DesFarmLand
= DesTotalLandUnderMgt*FracLandToFarm
DesFracLaborFarm
= LaborFarming/(LaborForce+.00001)
DesFracLaborFarmCutting
= DesLaborForFarmCutting/(LaborForce+.00001)
DesFracLaborPasture
= LaborPasture/(LaborForce+.00001)
DesFracLaborPastureCutting
= DesLaborPastureCutting/(LaborForce+.00001)
DesLaborForFarmCutting
= (DesFarmCutRate/CuttingPrdctvty)
DesLaborPastureCutting
= DesPastureCutRate/CuttingPrdctvty
DesPastureCutRate
= MAX(0,DesPastureLandAcquisitionRate-PotentialFarmConversionRate)
DesPastureLand
= DesTotalLandUnderMgt-DesFarmLand
DesPastureLandAcquisitionRate
= MAX(0,PastureDepletionRate+CorrforPastureLand+CorrPastureLandSL)
DesTotalLandUnderMgt
= LaborForce*AcresAbleToManagePerCapita
EffCovFarmConvRate
= GRAPH(FarmLandCov/NrmFarmCov,0,0.1,[0,0.62,0.83,0.94,0.99,1,1,1,1,1,1"Min:0;Max:1;Zoom"])
EFFFLDEPLRATE
= GRAPH(FARMCOVER/NrmFarmCov,0,0.1,[0,0.9,1,1,1,1,1,1,1,1,1"Min:0;Max:1;Zoom"])
EFFPASTCOV
= GRAPH(PastureLandCover/NrmPastureCov,0,0.1,[0,0.62,0.9,0.99,1,1,1,1,1,1,1"Min:0;Max:1;Zoom"])
EffRFCovFarmCutRate
= GRAPH(RFCov1/NrmRFCov,0,0.1,[0,0.91,1,1,1,1,1,1,1,1,1"Min:0;Max:1;Zoom"])

- EffRFCovPastureCutRate
  = GRAPH(RFCov2/NrmRFCov,0,0.1,[0,0.92,1,1,1,1,1,1,1,1,1"Min:0;Max:1;Zoom"])
- FARMCOVER
  = FarmLand/(IndFarmDepletionRate+.0000001)
- FarmLaborExponent
  = 1-FarmLandExponent
- FarmLandCov
  = FarmLand/(DesFarmConversionRate+.0000001)
- FarmPrdn
  = NrmFarmPrdn*(((FarmLand/INIT(FarmLand))^FarmLandExponent)*((LaborFarming/INIT(LaborFarming))^FarmLaborExponent))
- FarmRevenue
  = FarmPrdn*FarmPrice
- FracLaborFarmCutting
  = DesFracLaborFarmCutting/(TotalLaborFrac+.00001)
- FracLaborPastureCutting
  = DesFracLaborPastureCutting/(TotalLaborFrac+.00001)
- FracLandToFarm
  = 1-FracLandToPasture
- FracLandToPasture
  = GRAPH(PERRERETURNTOPASTLAND,0,0.2,[0.1,0.12,0.17,0.24,0.36,0.5,0.63,0.74,0.81,0.86,0.9"Min:0;Max:1;Zoom"])
- HectareRatio
  = HectaresAbleToManagePerCapita/(DesHectaresAbleToManagePerCapita+.000001)
- HectaresAbleToManagePerCapita
  = TotalHectaresUnderMgt/(LaborForce+.00001)
- HouseHolds
  = Population/NrmFamilySize
- IndFarmCutRate
  = LaborFarmCutting*CuttingPrdctvty
- IndFarmDepletionRate
  = FarmPrdn*PrdctvtyFarmPrdnOnDepletion
- IndFracLaborFarm
  = DesFracLaborFarm/(TotalLaborFrac+.00001)
- IndFracLaborPasture
  = DesFracLaborPasture/TotalLaborFrac
- IndPastureCutRate
  = LaborPastureCutting*CuttingPrdctvty
- IndPastureDepletionRate
  = PasturePrdn*PrdctvtyPasturePrdnOnDepletion
- InMigrFrac
  = NrmInMigrFrac*(AttractivenessEffect_1+AttractivenessEffect_2)
- LaborFarmCutting
  = LaborForce*FracLaborFarmCutting
- LaborFarming
  = LaborForce*FractLaborFarm
- LaborForce
  = Population*LFPR
- LaborPasture
  = LaborForce*FractLaborPasture
- LaborPastureCutting
  = FracLaborPastureCutting*LaborForce
- MARGINALREVPASTFARMRATIO
  = MarRevPrdctPasture/(MarRevPrdctFarm+.00001)
- MarPrdctvtyFarm
  = FarmLandExponent*(FarmPrdn/FarmLand)
- MarPrdctvtyPasture
  = PastureLandExponent*(PasturePrdn/(PastureLand+.00001))
- MarRevPrdctFarm
  = MarPrdctvtyFarm*FarmPrice

○ MarRevPrdctPasture
= MarPrdctvtyPasture*PasturePrice
○ PastureLaborExponent
= 1-PastureLandExponent
○ PastureLandCover
= PastureLand/(IndPastureDepletionRate+.0000001)
○ PasturePrdn
= NrmPasturefPrdn*(((PastureLand/INIT(PastureLand))^PastureLandExponent)*((LaborPasture/INIT (LaborPasture))^PastureLaborExponent))
○ PastureRevenue
= PasturePrdn*PasturePrice
○ PerCapitaProduction
= (FarmPrdn+PasturePrdn)/Population
○ PerCapitaRevenue
= (FarmRevenue+PastureRevenue)/Population
○ PotentialFarmConversionRate
= FarmLand/NrmConversionTime
○ RFCov1
= RainForest/(IndFarmCutRate+.00001)
○ RFCov2
= RainForest/(IndPastureCutRate+.0000001)
○ TotalHectaresUnderMgt
= FarmLand+PastureLand
○ TotalLaborFrac
= MAX(1,DesFracLaborFarm+DesFracLaborFarmCutting+DesFracLaborPasture+DesFracLaborPastureCutting)
○ TotalLandUnderMgt
= FarmLand+PastureLand
○ TotalRevenue
= PastureRevenue+FarmRevenue
◇ AcresAbleToManagePerCapita
= 5
◇ AttractivenessEffect_2
= 0
◇ AveLifeSpan
= 70
◇ AveTimeToRainForest
= 500
◇ AveTimeToSecondForest
= 12
◇ BirthRateCoef
= .002
◇ CuttingPrdctvty
= 7
◇ DesHectaresAbleToManagePerCapita
= 5
◇ FarmLaborAdjustTime
= .5
◇ FarmLandExponent
= .05
◇ FarmPrice
= 24
◇ FracReclaimFarm1
= .9
◇ FracReclaimFarm2
= .9
◇ FracReclaimPasture
= .9
◇ LFPR
= .9
◇ NrmConversionTime
= 1

◇ NrmFamilySize
= 5
◇ NrmFarmCov
= 10
◇ NrmFarmPrdn
= 100
◇ NrmInMigrFrac
= .025
◇ NrmPastureCov
= 5
◇ NrmPasturefPrdn
= 10
◇ NrmRFCov
= 3203.4
◇ OutMigrFrac
= .0005
◇ PastLaborAdjstmentTime
= .5
◇ PastureLandExponent
= .5
◇ PasturePrice
= 30
◇ PrdctvtyFarmPrdnOnDepletion
= .25
◇ PrdctvtyPasturePrdnOnDepletion
= .15
◇ TimeCorrFarmLand
= 1
◇ TimeCorrPastureLand
= 1
◇ TimeCorrPastureLandSL
= 1
◇ TIMEPERRELRTRNPASTLAND
= 2