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Influence of Transmigration on Sustainable Agriculture in Southeast Sulawesi, Indonesia

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Abstract—In the 31 years of the Sulawesi transmigration program that ended in 1998, a strong correlation between population and food crops production was observed. As a product of the increasing numbers of people added each year, the Sulawesi population grew by 2.99% with food production increasing by 4.87%. This study indicates that it is feasible, using system dynamics, to simulate sustainable agriculture while concurrently estimating population increase and land availability. From 1998, the model used a time span of 50 years. Analysis shows that the agricultural land sector grew steeply from the 20th to 30th year, overshooting the population curve. From the 25th year on, nonagricultural land increased while agricultural labor decreased. Results likewise show that population/land and population/agricultural land declined until the 30th year, and growth was reduced by as much as 50%. Until the 27th year, the ratio of agricultural production to population had been adequate. All variables in the system have been equilibrium-seeking since the 30th year. The fundamental role of resource constraints in controlling growth and bringing about equilibrium is clearly observed in this model. This study also shows that agricultural land development precedes nonagricultural land development. Agricultural land decline is mainly due to nonagricultural land conversion, such as for public facilities, environmental purposes, and other construction. Deregulation in the form of a multiplier and an adaptive system construction is needed to sustain agriculture from the 30th year.

Introduction

Indonesia is an archipelago consisting of 17,508 islands, of which only about 7% are inhabited. Indonesia's remarkable growth record has been marked by regional imbalances arising from geographic variations in population and resource endowment. The highest levels of development have occurred in Java and Bali, which together support 60% of Indonesia's population. These islands are endowed with the most fertile agricultural lands and have the most developed infrastructures. The government of Indonesia has made every effort to ease the burden of densely populated regions and to upgrade regional development. This has been done by opening productive areas and new settlements, the utilization of natural resources, the creation of more job opportunities, and the provision of more equitable welfare for the people for many years.

With the development of transmigration areas, including the required infrastructure and facilities for transportation, communication and electric power, the increase in population, and the increase in economic activity, it is hoped that the areas outside Java will become attractive to investors and that new inhabitants will arrive of their own accord. In this way the transmigration program has functioned by supporting the development of areas outside Java, thus accelerating equalization of inter-area development and reversing the direction of migration.

The transmigration programs in Indonesia can be seen not only as a way of reducing the population pressure on the land or the overcrowding problem in Java, but also as a rational step to mobilize agricultural plantations in Sumatra. In other words, present agricultural development policies will somewhat affect the future growth of the industry. This can also be considered regional development scheme, since the transmigration program acts to correct the socioeconomic imbalance of less developed regions. Such actions create planned settlement schemes in the new areas, and at the same time improve the living standards of the overcrowded areas. Obviously if the programs work well, agricultural production will be increased, jobs will be created and rural people will be better off economically. Sustainable agricultural development most likely will persist under this condition (Mustapha 1993).

Transmigration efforts in the agricultural sector are also expected to increase the area under agricultural production thereby increasing production and exports. In view of the many developmental aims, which are related to the transmigration program, it is clear that this program is an integral part of the developmental efforts in Indonesia's plan and beyond. Also Romer (1996) stated that it is possible, at least up to the point where resource limitations become important, that the larger population is beneficial to the growth of worldwide knowledge. In other words, the larger the population is the more people there are to make new discoveries.

Sustainable development is a process in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony, and enhance both current and future potentials to meet human needs and aspirations (Redclift 1990). Success in sustaining agriculture, on the other hand, will produce positive effects on the economy of a country and of the world. Sustainable agriculture is a necessary ingredient of the sustainable developmental process (Adulavidhaya 1993). If regional agriculture stagnates, the local economy has no engine to drive non-farm activities.

The objective of this paper is to show how system dynamics based on a previous empirical study and on Forrester's theoretical paradigm (Minegishi & Thiel 2000) could contribute to improving the knowledge of the complex logistic behavior of a sustainable agriculture. The objective is also to study system behavior to identify and modify the symptoms of instabilities in such sustainable systems, rather than the true causes. After a short presentation of this research, the structure of a generic model and some significant practical simulation results are presented as applied to the field.

Characteristics of the Southeast Sulawesi Regional

The Province of Southeast Sulawesi is located in the Southeast Gulf of Sulawesi Island between 3º–6º S and 120º45'–124º60' E. The total land area of Southeast Sulawesi is estimated at 38,140 km^2, and the sea area is about 110,000 km^2 (Central Bureau of Statistics 1995).

In 1998, the population of Southeast Sulawesi was 1,672,659; and a total of 54,724 transmigrant families or almost 210,588 people have moved between 1968 and 1997 to 157 settlement units in the area. From the viewpoint of demographic impact, transmigration contributed to 2.99% of the annual population growth of the province during that period. Most transmigrants came from Java, Bali, Madura, and the Lombok Islands. Transmigrants are estimated to account for 12.60% of the population of Southeast Sulawesi. Growth of population, transmigrants coming, and food crops production during the period from 1968 to 1998 in detailed is presented in Table 1.

A remarkable feature of the provincial economy is that the share of agriculture in Gross Domestic Product (GDP), 35.02% in 1997 and already one of the highest in the country, has actually been rising (Central Bureau of Statistics 1998). Southeast Sulawesi is the only province in which such a trend is clearly evident; it is explained by the consistently high growth across all agricultural subsectors

Table 1. Growth of population, transmigration and food crops production in Southeast Sulawesi, 1968-1998.

Year	Population	Total transmigrants coming	Food crops production (tons)
1968	5.99		
1969	1.26	106.00	18.91
1970	2.99	48.91	-6.14
1980	3.10	154.64	3.23
1990	3.66	21.18	7.43
1995	3.29	43.25	2.88
1996	2.64	2.87	2.61
1997	3.35	3.20	-7.12
1998	1.45	0.37	17.79
Annual average growth (%)	2.99	14.40	4.87

Sources: Data for 1968-1998 supplied by Provincial Statistical Office of Southeast Sulawesi

Table 2. Southeast Sulawesi growth and distribution of Gross Domestic Regional Product (GRDP), 1974-1997 (percentage)

Sector	1974	1983	1993	1994	1995	1996	1997
Agriculture	41.80	50.30	33.73	33.13	33.41	33.70	35.02
Mining and quarrying	21.70	9.30	3.06	2.91	3.00	3.96	3.81
Manufacturing industries	1.30	0.70	5.58	6.84	9.76	8.18	8.38
Utilities/electricity, gas, and water supply	n	0.30	0.56	0.53	0.53	0.53	0.61
Construction	1.60	2.70	12.34	12.90	11.90	11.57	10.94
Trade, hotel, and restaurant	13.50	10.20	11.32	11.22	10.94	11.55	12.65
Transport and communication	2.50	9.40	8.06	7.57	6.85	6.86	6.65
Financial, dwelling and business	n	0.90	5.34	5.05	4.65	5.57	5.06
Accommodation	5.00	4.50					
Public administration	12.00	11.10					
Services	0.60	0.60	20.01	19.85	18.96	18.08	16.88
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Data supplied by Central Bureau of Statistics of Southeast Sulawesi
Notes: Distribution at current price
n= Negligible (less than 0.10 percent)

Table 3. Population 10 years old of age and over of Southeast Sulawesi who worked by industry.

Industry	1992	1993	1994	1996	1997	1998
Agriculture	66.91	64.08	61.21	55.56	54.77	56.79
Mining	1.52	1.31	1.33	1.57	1.93	1.72
Manufacturing	3.28	3.76	4.33	7.15	8.08	6.21
Electricity	0.26	0.20	0.16	0.19	0.18	0.27
Construction	2.09	2.56	2.29	14.25	3.26	3.56
Trade	8.69	12.04	10.88	3.54	14.44	14.06
Transportation/communication	2.14	1.81	2.29	2.48	2.80	3.06
Finance	0.11	0.27	0.31	0.20	0.27	0.22
Services	13.21	13.39	16.65	14.95	13.99	14.00
Others	1.80	0.58	0.55	0.10	0.28	0.09
Total	100.00	100.00	100.00	100.00	100.00	100.00

Source: Central Bureau of Statistics of Southeast Sulawesi Province (1995, 1996, 1998). Central Bureau of Statistic Jakarta (1998).

(Table 2). As would be expected, in 1998 the labor force in this province was essentially agrarian, with at least 56.79% engaged primarily in agriculture and about 14.06% in the trading sector, which is the next largest source of employment (Table 3).

In Southeast Sulawesi, general agricultural development still dominates rural development. Based on the information from various sources, there are more than 1.2 million ha of land, which can be used for farming activities. More than one million ha are dry land and only 120,000 ha can be used for wetland cultivation. The type of land utilization and the land available for expansion of agricultural in Southeast Sulawesi is presented in Table 4 (Government of the Southeast Sulawesi Province 1987).

Table 4. Land in Southeast Sulawesi by type utilization (ha)

Land utilization	1987	1993	1994	1995	1996	1997	1998
Wetland	49,914	61,695	64,297	66,589	67,564	64,297	81,433
House compound and surroundings	116,546	113,406	98,868	111,158	101,430	98,868	118,855
Wasteland/garden/field/ shifting cultivation	329,884	323,478	333,460	339,214	350,517	334,260	324,446
Meadows	81,145	74,732	95,617	99,693	94,702	95,617	114,939
Unused swamp	71,224	89,994	108,763	98,399	86,113	106,763	97,171
Dykes and waterpond	5,497	10,814	10,547	9,562	9,562	10,547	10,770
Temporarily fallow land	413,917	346,087	342,218	338,629	349,317	342,218	280,546
Wooded land	268,194	257,847	219,779	208,079	221,119	219,779	228,647
Forest	1,868,316	1,880,146	1,891,979	1,914,434	1,883,207	1,891,979	1,863,689
Estates	274,453	398,028	412,717	393,630	414,685	412,717	418,660
Other land	334,910	257,773	236,955	234,613	235,784	236,955	274,844
Total	3,814,000	3,814,000	3,814,000	3,814,000	3,814,000	3,814,000	3,814,000

Source: Central Bureau of Statistics of Southeast Sulawesi (1987, 1995, 1996, 1998).

Table 5. Factors influencing change in food crops production in Southeast Sulawesi, 1968-1997.

	Percentage of growth in production due to		
	Intensification	Extensification	Combination effects
Wetland paddy	18.61	45.53	35.86
Upland paddy	-73.92	153.60	20.32
Maize	241.41	-52.76	-88.65
Soybean	0.05	93.36	6.59
Cassava	241.15	-56.60	-84.55
Total food crops	65.78	23.34	10.88

Virtually all crops in Southeast Sulawesi were produced under rainfed conditions. Only a limited crop area was under controlled irrigation and drainage. Our study of the 1968-1997 trends in the production of major food crops in Southeast Sulawesi reveals that the dominant contribution of the transmigration program on food crops production has been linked to agricultural policy, which witnessed increases in upland paddy (153.60%), soybean (93.36%), and wetland paddy (45.53%). Furthermore, as a whole, the transmigration program represented 23.34% of the increase in food crops output for Southeast Sulawesi during the 30 years ending in 1997 (Table 5).

Farmers in Southeast Sulawesi also grow industrial crops such as coconut, coffee, cacao, cashew nut, nutmeg, clove, cotton, and tobacco. Until 1996 the dominant industrial crops was cacao, coconut was second, and the third important commodity in industrial crops production was cashew nut. Table 6 illustrates the situation in the period 1978-1996. The government supported the expansion of industrial crops commodities in earning foreign currency because the price and demand of industrial crops in the world market increased.

Table 6. Industrial crops products (ton) by type in Southeast Sulawesi, 1978-1996

Year	Coconut	Coffee	Cacao	Cashew nut	Nutmeg	Clove	Cotton	Tobacco	Total	Annual average growth (%)
1978	16,212	733	3	1,131	112	6	30	151	18,378	
1979	16,673	748	6	1,316	218	6	1,081	85	20,133	9.55
1980	16,866	1,017	7	1,290	210	11	1,844	88	21,333	5.96
1981	18,254	1,052	353	1,512	225	39	1,022	102	22,559	5.75
1982	16,890	3,354	1,600	4,303	203	47	2,076	33	28,506	26.36
1983	12,050	743	1,957	4,440	259	88	3,459	82	23,078	-19.04
1984	22,136	1,847	9,561	12,882	178	331	1,635	59	48,629	110.72
1985	23,859	1,948	13,234	15,348	165	530	1,544	55	56,683	16.56
1986	22,584	2,051	16,906	17,815	151	729	1,453	50	61,739	8.92
1987	27,307	2,153	20,580	20,282	139	929	1,362	45	72,797	17.91
1988	29,031	2,254	22,749	22,749	125	1,128	1,270	40	79,346	9.00
1989	30,754	2,357	25,216	25,216	112	1,327	1,179	36	86,197	8.63
1990	33,993	2,435	23,567	32,571	58	852	405	0	93,881	8.91
1991	41,323	2,900	37,577	45,325	57	1,577	845	27	129,631	38.08
1992	39,897	2,561	41,712	30,325	61	1,617	387	44	116,604	-10.05
1993	40,781	2,592	53,814	33,023	33	2,202	349	11	132,805	13.89
1994	38,339	2,887	50,866	33,772	33	3,600	502	67	130,066	-2.06
1995	35,993	2,435	55,165	31,046	24	2,999	163	21	127,846	-1.71
1996	35,916	2,459	56,197	32,063	18	2,720	301	21	129,695	1.45
Average growth (%)										13.82

Source: Data for 1974-1996 supplied by Provincial Statistical Office of Southeast Sulawesi. Central Bureau of Statistics, various issues, statistical year book of Indonesia.

Methods

This paper presents simple ideas for the analysis of sustainable agriculture on the scale of regional communities, and gives an outline of sustainable agriculture under some tentative parameters based on a few assumptions from a modeling perspective. The assumption of this model is not limited by the agricultural production needed, neither by how many ha is available to be opened, or to the degree that agriculture can support the population. The hypothesis is based on experience and experiment in Southeast Sulawesi; therefore this model can be used. The model is derived from statements, observations, and assumption about the sustainable system and comes from a non-linear function, fitting it and setting it to a more appropriate data. The interpretations are based on the behavior of the computer model. The computer model interconnects concepts from demography, land, and agriculture.

In general, however, dynamic simulation models are better suited to predict changes in land use than empirical, stochastic or static optimization models, although some stochastic and optimization methods may be useful in describing the decision-making processes that drive land management (Lambin et al. 2000).

The model that we use here is just the mid-term position of the total system model with a time span of 50 years starting from 1998. The model consists of agriculture, land, and population. The transmigration position in this model is controlled by the Attractiveness for Migration Multiplier. The sector in Southeast Sulawesi province is not only on an agriculture sector, but other economic and social factors are also available. The next step of the analysis is the industrial sector, the environment, and whether a social indicator can be built or introduced into this simulation.

System dynamics is a method of calculating complex system behaviors on a computer simulation model, based on the causal relationships among inner system factors with information exchanges (Takeuchi & Nagahasi 1993). The system dynamics model and its methodology put emphasis on conceptualization, formulation and simulation. It is divided into two stages: qualitative and quantitative analysis.

In the first stage, we identify system variables for the problem in question and develop a qualitative system model in the form of a causal loop diagram. In the second stage, the qualitative model is transformed into a system flow diagram and is calibrated for quantitative analysis using simulation techniques (Quaddus & Intrapairot 2001). To approach the complexity of the management of these sustainable flows, an analysis of the behavior of the sustainable system has been chosen using Forrester's system dynamic and from a macroscopic point of view.

Results and Discussions

Basic Structure of the Model

To approach the complexity of the management of sustainable agriculture, in this study, we will consider a simple flow chart model consisting of four subsystems (land use sector, agricultural production sector, agricultural labor sector, and population sector) and five interactive levels (agricultural land use sector, nonagricultural land use level, agricultural production sector, agricultural labor level, and population sector) (Figure 1).

This simple agricultural flow system has potential for application in sustainable agriculture since some of the factors are widely used in predicting population and agricultural production growth. In the assessing the system dynamics model or interactive factor, a hypothesis was employed. Technological level, live quality condition, and social condition are also important factors, but because no complete data is available we cannot do an observation for these factors. This interactive sustainable structural flow chart, in reality has many more material and information flows than presented here, and some of them cause consequence variables mixed between themselves and their environment.

Qualitative Analysis

The qualitative system dynamics begin with creating a causal loop diagram (i.e. to identify information feedback loops facilitates) and understanding of how

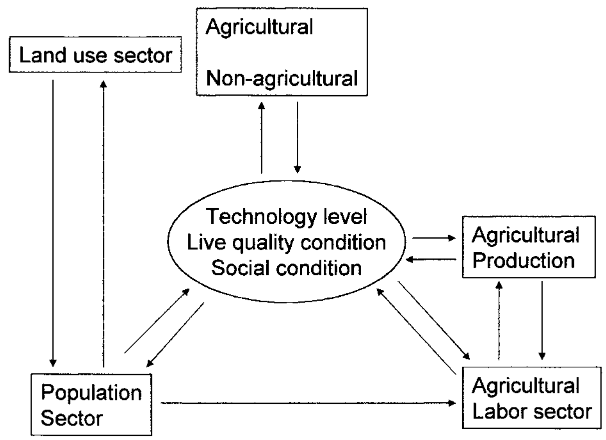


Figure 1. Flow chart model.

processes, organizational boundaries, delays, information, and strategies of systems interact to create system behavior. The qualitative model developed was based on various data information collected during the study.

Before discussing the specific structure chosen here, the general nature of the structure as found in all dynamic systems will be summarized. Within the feedback loops of a system, the principles of system structure tell us that two kinds of variables will be found; levels and rates. The levels are the accumulation (integration) within the system. The rates are the flows that cause the levels to change. In the figure, the system levels appear as rectangles. A level accumulates the net quantity that results from the flow rates that add to and subtract from the level. The system levels fully describe the state or condition of a system at any point in time. Each level is increased or decreased by its associated rate of flow. An example of a flow is the valve symbol; levels are caused to change only by rate of flow. Conversely, rates depend only on system levels through an information network as shown by the dashed lines and circles. A system structure consists only of levels and rates. The circles in the diagram are parts of the rate descriptions but have been separated from the rate symbols because they are concepts that are more clearly described independently. The irregular cloud symbols are sources or sinks for the flows and lie outside the system. For each symbols in the figure there is a name or a number (Forrester 1973, Minegishi & Thiel 2000). The qualitative analysis in this study consists of population sector, land use sector, agricultural production sector, and agricultural labor sector.

Population Sector

The population in Figure 2 is a system level with Attractiveness for Migration Multiplier and Land Development Attractiveness for Migration Multiplier as increasing factors (i.e. inflow). Also present is the Land Development Attractiveness for Migration Multiplier as a factor for controlling the population.

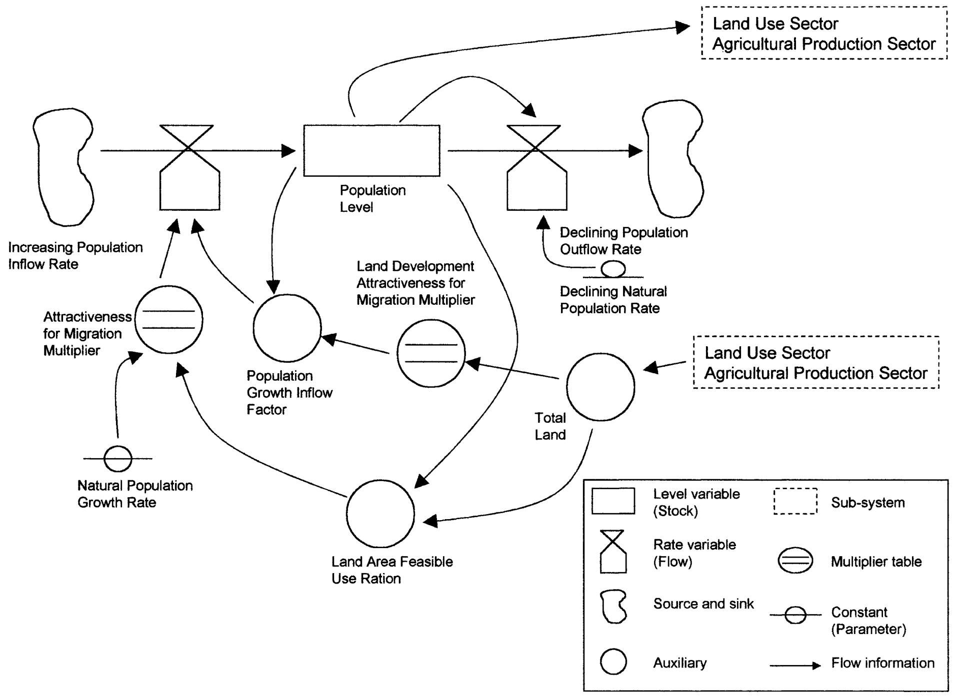


Figure 2. Population sector.

If the population is high and the available land is low then the multiplier will go down and the population in turn will also become low. A Declining Natural Population Rate functions as a decreasing factor (outflow). Another decreasing factor is the Land Area Feasible Use Ratio which acts as a feedback mechanism to reduce the Attractiveness for Migration Multiplier and in turn suppress population increase. The availability of land makes people come to this area, and it is controlled by the Land Area Feasible Use Ratio. The causal loop diagram further indicates that all the rates depend directly on the population level.

The in and out subsystem of the population sector are the Land Use Sector and Agricultural Production Sector. Bongaarts (1995) stated that at the country and regional levels, population growth can also be affected by migration, but for large aggregates of population, such as those used in this analysis, migration is a sufficiently minor factor and may be ignored.

The rates written in this qualitative population sector as well as other qualitative sectors are called “normal” rates because they correspond to a standard set by common conditions when the values of food, material standard of living, crowding, and pollution are at all at their “standard” values. But other system variables can change when introduced through “multipliers” that increase or decrease the normal system rates. It is through these multipliers that the condition of the system, as reflected in agricultural production, material standard of living, land, and labor, can cause the population to increase, remain stable, or decline.

In a similar way, the causal loop can be seen in Figure 2. As the population acts through the Land Area Feasible Use Ratio to reduce the land available for agriculture, the Land Development Attractiveness for Migration Multiplier also adjusts the population to maintain balance with land supply.

From the causal loop diagram of the population sector, we can see that the Attractiveness for Migration Multiplier depends upon the Land Area Feasible Use Ratio. The attractiveness variable requires a table function to describe its nonlinear relationship with the Land Area Feasible Use Ratio. For the moment, we will simply assume that, as the Land Area Feasible Use Ratio varies, the area becomes more or less "normally" attractive.

The population model, although a relatively simple structure, illustrates a number of important dynamic concepts. During growth, the area attracts migrants. Once the land constraint begins to depress construction, however, the community loses its attractiveness for migration. The population stabilizes when Land Area becomes sufficiently unattractive for migrants and the area population.

LAND USE SECTOR

The causal loop diagram indicates that the level of agricultural land area is increased by agricultural development and the agriculture development Feasible Acquisition Multiplier. It is decreased by devastation of the land area. In fact, there are many decreasing factors of the quality of the agricultural land, but we analyzed just the devastation factor. In our analysis the devastating value is con-

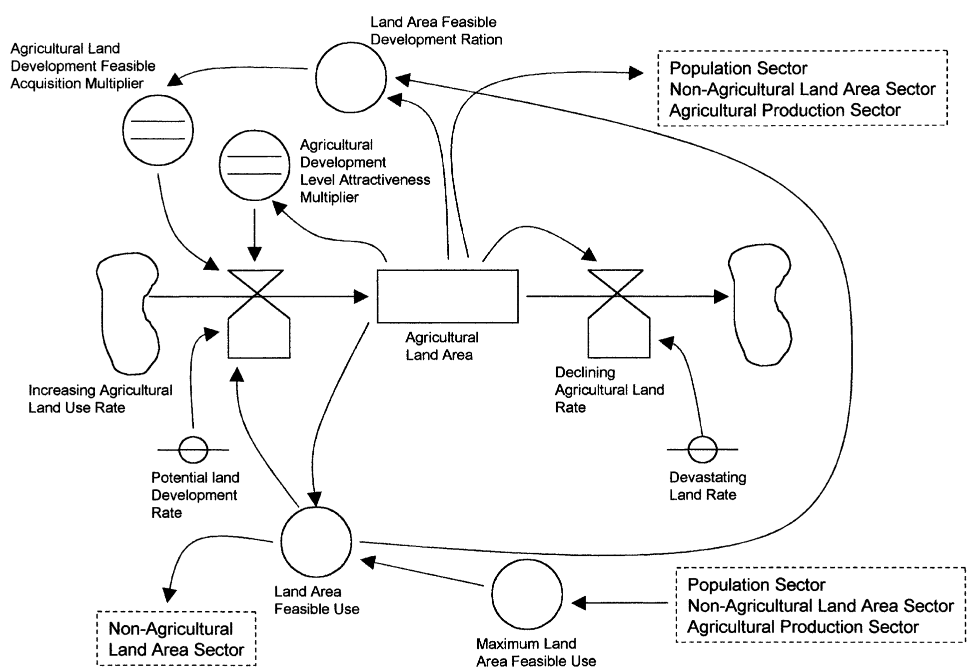


Figure 3. Land use sector.

stant, but in another analysis it will be explained with other variables. Figure 3 shows the assumption that from the Agricultural Development Level Attractiveness Multiplier it can be observed that the increasing factor is bigger than the decreasing factor. For the development of agriculture, budget support from the government is needed until the takeoff of the development phase.

The causal loop diagram further indicates that this system has an in-subsystem connected to the population sector, nonagricultural land area sector, and the agricultural production sector. It also has an out-subsystem connected to the population sector, agricultural production sector, and the agricultural labor sector.

In this paper we do not present causal loop for nonagricultural land area. The Maximum Land Area Feasible Use Auxiliary should be divided into agricultural land sector and nonagricultural land sector. The key point is that there is tradeoff between the agricultural land and the nonagricultural land sector. If agricultural land increases then nonagricultural land will decrease, and vice versa. In connection with sustainable agriculture this competition is decided by policy. It is better, however, that the first development is in the agricultural land sector, followed by the nonagricultural land sector. Other components of this sector will be decided by population growth.

Agricultural Production Sector

Figure 4 shows a possible model of the agricultural production sector. The level (stock) in the model is Agricultural Production Level. Agricultural production increases by the Agriculture Production Demand Multiplier, Effectiveness

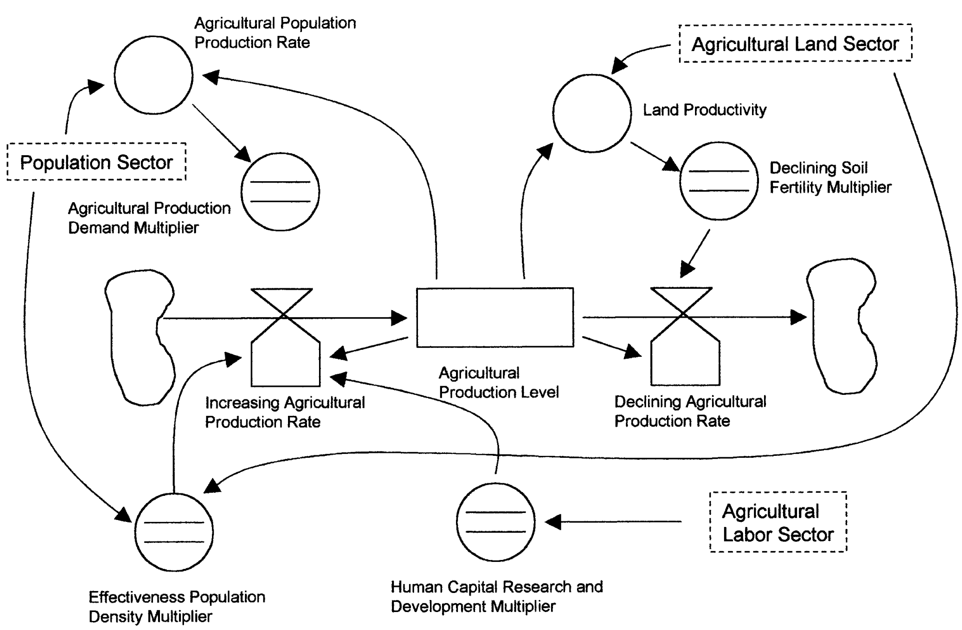


Figure 4. Agricultural production sector.

Population Density, and Human Capital Research. It decreases by the Agriculture Population Production Rate and Effectiveness Population Density Multiplier.

Of special note for this model is that the Agricultural Production Demand Multiplier is affected by the Population Sector. This means that the population decides the agricultural production. This fact is not found in the traditional agricultural system. The multiplier shows that as population increases, the agricultural production becomes larger. Land Productivity is the product of Agricultural Land Sector and Agricultural Production Level.

Effectiveness Population Density Multiplier is rolled for increasing population. If population density increase then agricultural production also increase.

The Population Sector is exogenous while Human Capital and Development Research are endogenous. This Human Capital and Development Research factor assumption are related to the high yield paddy production in and out of Java Island, and this leads to a high per capita production. The increasing of paddy yield in Indonesia can be seen in Figure 5.

According to Forrester (1973) the usage of natural resources depends on the population and the material standard of living which reflects the amount of capital investment. It is better to invest in human capital (research, knowledge and education) that does not deplete resources. In addition, the accumulation of human capital is broadly similar to the accumulation of physical capital. Devoting more resources to the accumulation of either type of capital, increases the amount of output that can be produced in the future (Romer 1996). The main engine of growth is the accumulation of the human capital of knowledge. The main source of differences in the living standards of nations is the difference in human capital. Physical accumulation plays an essential but decidedly subsidiary role. Human capital accumulation takes places in schools, research organizations, and in the course of producing goods and engaging in trade (Rodrigo & Thorbecke 1997).

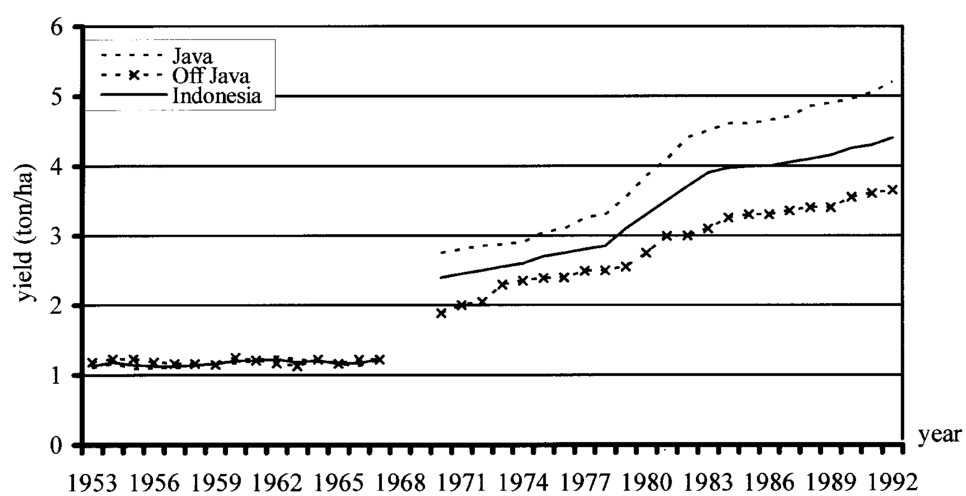


Figure 5. Yield of paddy, 1953-1992. Source: Mears et al. (1968), Gonzales et al. (1993), Hill (1996).

The human dimensions are key elements to consider in this intricate set of relationships and they should be adequately taken into consideration in comprehensive policies for sustainable development. Such policies should address the linkages of demographic trends and factors, resource use, appropriate technology dissemination, and development. Population policy should also recognize the role played by human beings in environmental and development concerns (Edwards et al. 1993).

Agricultural Labor Sector

Agricultural labor is a level of this model. It has as increasing factors the Capital Stock Multiplier and Total Labor, and Agricultural Labor Productivity and Intensity Extension Multiplier as decreasing factors (Figure 6). The Capital Stock Multiplier functions as an increasing or decreasing factor of labor productivity. When the Capital Stock Multiplier becomes high, then productivity also goes up. The Intensity Extension Multiplier's function is to reduce Agricultural Labor. When it is high Agricultural Labor decreases. Similarly, if productivity is high, little labor is needed because an excess supply of labor occurs. This resembles the case in the Malthusian trap with lower labor productivity.

In-and out-subsystems are the Population Sector and the Agricultural Production Sector, respectively. In order to achieve a good model, the Population Sector should be chosen first, followed by other subsystems. The value of the

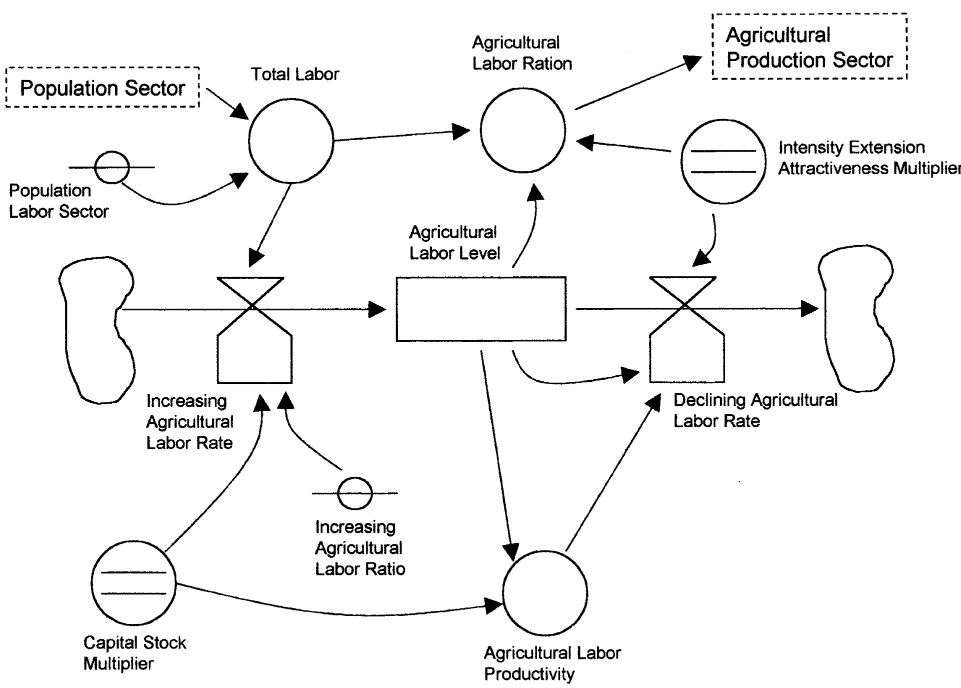


Figure 6. Agricultural labor sector.

Population Labor Sector used in this model is constant, but in the next step it can be changed to become a variable. Technology that keep soils in near-continuous production requires dense populations to ensure adequate labor (Clay et al. 1994).

A sustainable model implies greater reliance on human resources in terms of the quality and quantity of labor and management. It is relatively less reliant on land and capital. Thus, sustainable farming systems may require more farm operators, more farm laborers, and more farm families than do conventional farming systems (Ikerd 1993).

Human capital consists of the abilities, skills, and knowledge of particular workers. In addition, the accumulation of human capital is broadly similar to the accumulation of physical capital. Devoting more to the accumulation of physical capital increases the amount of output that can be produced in the future (Romer 1996). Greater investment in physical capital clearly leads to higher labor productivity (Rodrigo & Thorbecke 1997).

Quantitative Analysis

Social systems usually exhibit fundamental conflicts between the short-term and long-term consequences of a policy change. The short-term consequences are more visible and more compelling and speak loudly for immediate attention. A series of actions all aimed at short-term improvement can eventually burden a system with long-term depressants so severe that even heroic short-term measures no longer suffice. Many of the problems that the world faces today are the ultimate result of short-term measures taken over the last century (Forrester 1973).

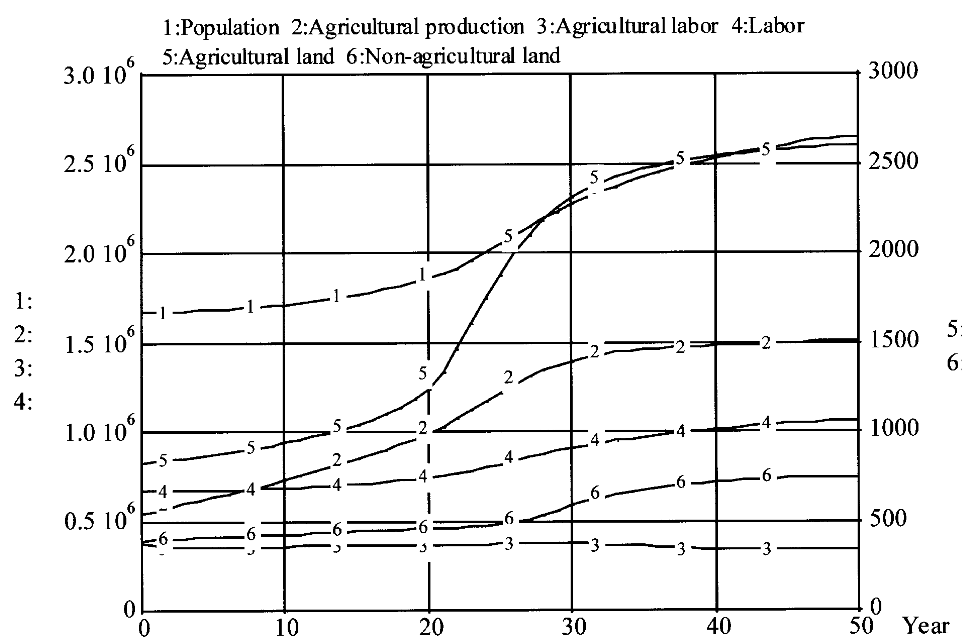


Figure 7. Base run simulation.

In this study, the quantitative analysis consists of a base run simulation, main indicator ratio, annual growth rate simulation, case-I high farming, and case-II sustainable agriculture.

Base Run Simulation

The time span for all simulations in this study is 50 years starting from 1998. Figure 8 long-range projections that suggest that the Southeast Sulawesi Province population will continue to grow through to the year 2048, eventually reaching totals of 2.6 to 2.7 million or higher. Land is of varying quality, so there is a need for more intensive use of the land. The population increase will be gradually slowed to keep the food ratio from falling.

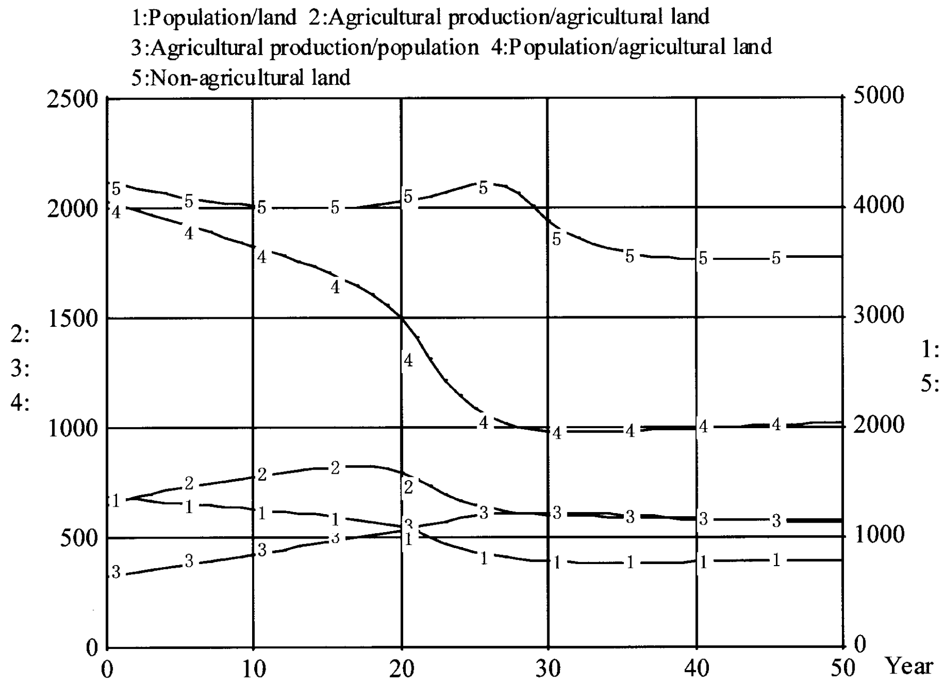
A commonly observed mode of behavior in a dynamic system is S-shaped growth which combines both exponential and asymptotic growth. In case of S-shaped growth, the system does not reach equilibrium (Goodman 1983, Sterman 2000). Quaddus and Intrapairot (2001) suggest that a new technology should not be adopted all at once. However, some early adopters adopt new technology all at once. If the technology diffuses relatively rapidly, the S-shaped curve becomes steep. On the other hand, some technologies may have a slower rate of diffusion resulting in a relatively flat S-shaped curve. S-shaped growth is also known as "logistic or sigmoid growth". This happened in the agricultural land sector with steep growth from the 20th to 30th year and an overshoot of the population curve (Figure 7).

Naturally, not all of the unused land should be considered to be a reserve for only agricultural expansion. It is also for nonagricultural use such as infrastructural, economic and environment purposes. However, these numbers put in proper perspective that increasing land scarcities is a constraint on agricultural growth. Our analysis shows that since the 25th year nonagricultural land increased, meanwhile agricultural labor decreased.

Main Indicator

Figure 8 shows the two fundamental simulations of the main indicator in this system. The upper figure shows land, as a natural resource, and population. The lower figure shows labor conditions. They represent the indicator of increased and decreased agricultural production and productivity of agricultural labor.

The result shows that the curve of population/land and population/agricultural land declined until the 30th year and the growth reduced almost by 50%. As predicted, the availability of land for the increasing population is low. Also, the result shows that the part of the land suitable for agricultural has become lower. As the amount of land per person declines, the adequacy of food supply will rapidly fall, reaching zero if no agricultural land remains. Increasing population would force more intensive use of the land. It may also reduce the available food-growing land as well as force agricultural production onto marginal land with lower productivity. Capital investment must be employed to compensate for poorer natural conditions.



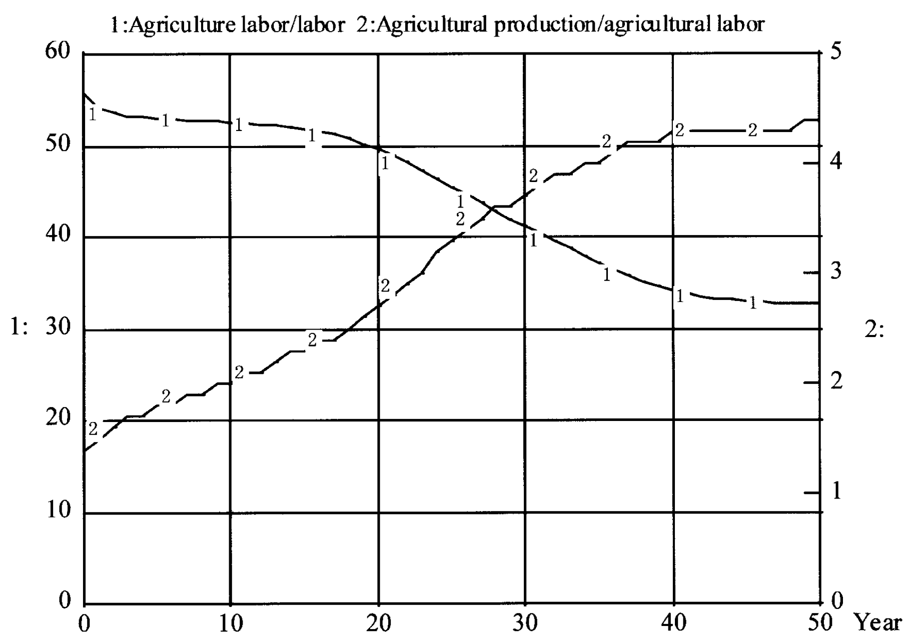


Figure 8. Main indicator ratio.

The disappearance of farmland has been masked by rising productivity per unit area such as shown in the agricultural production/population graph. It can be obtained by farm mechanization, irrigation, and improved varieties of plants. This, however, cannot continue without limit. Until the 27th year of the model the ratio of agricultural production to population was adequate after that it became stable. As we can see, all variables in the system have been equilibrium-seeking since the 30th year. The fundamental role of resource constraints in controlling growth and bringing about equilibrium clearly emerges in this model. The assumption of a finite amount of land available for sustainable agriculture dominates the system's behavior.

The lower figure shows the scissor-type curve between agricultural labor/labor and agricultural production/agricultural labor. The agricultural labor/labor curve tends to decline in an opposite direction to the agricultural production/agricultural labor curve. Both curves have a point of intersection at the 28th year of the model. This means that total agricultural labor will decrease along the period of the model and will be compensated by technology, to increase the productivity of the labor. The growth changes from the original model that are combined in this figures are agricultural labor/labor (which is reduced by 38.10%) and labor productivity (which is increased by 800%).

Annual Growth Rate Simulation

Figure 9 is an assumption that we hope will happen in the Southeast Sulawesi region. In the first year of the simulation agricultural labor started with a minus value and reached a minus peak in the 33rd year. Agricultural land, population, and agricultural production grew in parallel, but agricultural land grew steeply, reaching a peak at the 23rd year and thereafter declined.

This study also shows that agricultural land development comes before non-agricultural land development. This figure also explains the decline of agricultural land by conversion to nonagricultural land, such as for public facilities, environmental purposes, and other constructions. The gradual peaking and decline of all variables in the system are equilibrium-seeking toward zero growth (Figure 9).

Case I—High Farming

In this session a case study of high farming is presented to show an example of the application of this study. The objective of this simulation is to understand the behavior of the high farming system in sustainable agriculture. The high farming case simulation is shown in two figures (Figure 10). In the upper figure, most of the variables, except production, are developed basically from the previous analysis base run simulation. This figure shows that since the 25th year, as industrialization progresses, some of the agricultural land has been converted to industrial sites.

As shown in the lower figure, an assumption of high farming is the heavy usage of inputs or investments in machinery, chemicals, etc. for agricultural production. From the first to the 5th year, agricultural labor growth rate increased

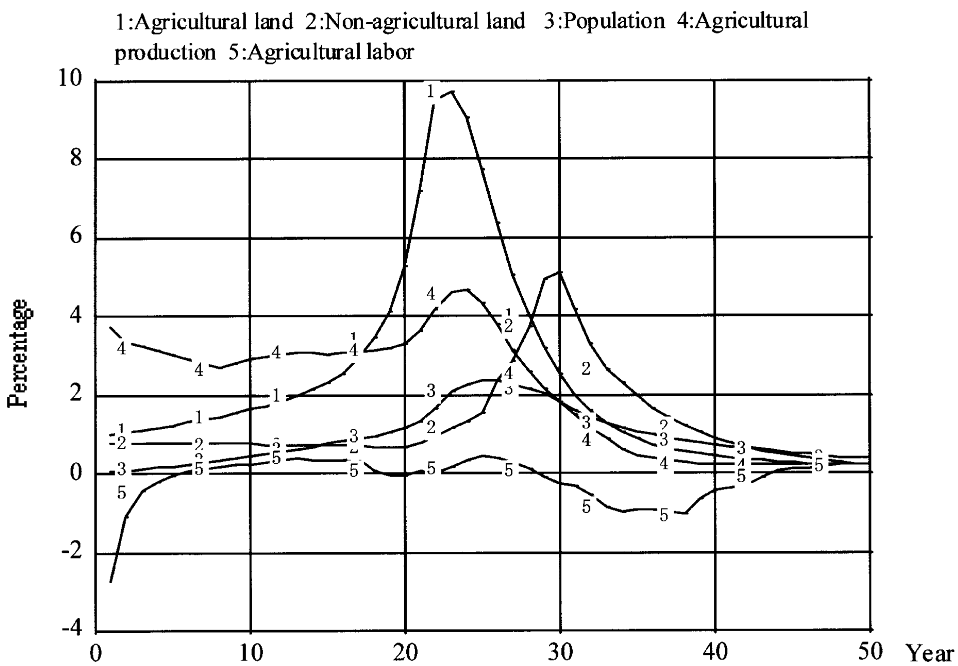


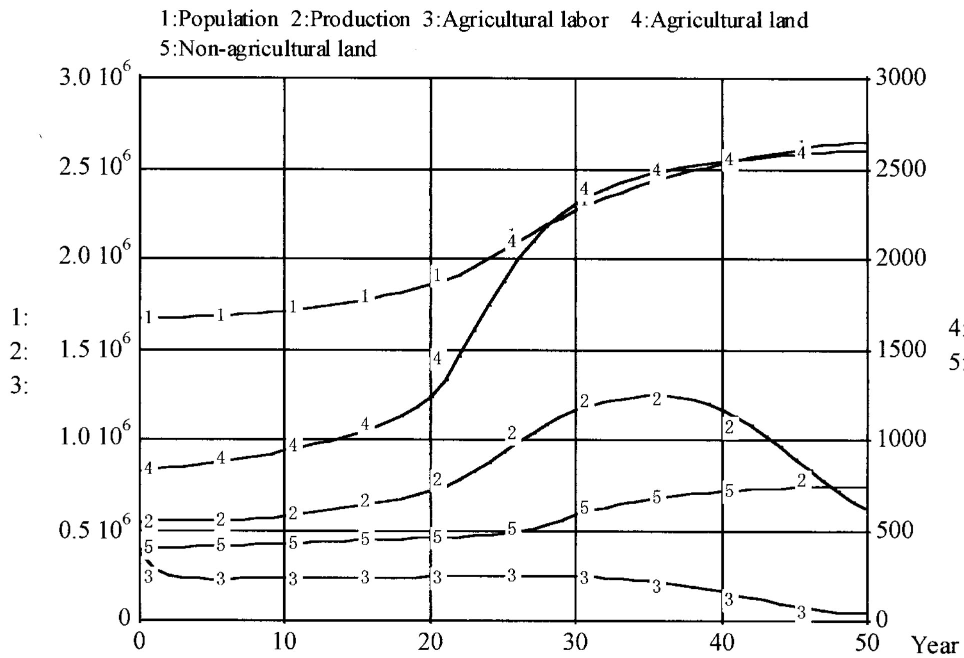
Figure 9. Annual growth rate simulation.

steeply in the process of overall modernization. When reaching a positive value it then stayed at equilibrium until the 23rd year, and thereafter it decreased very rapidly to a negative value again. This system uses only a few agricultural labors, and it can be seen that at the end of the year, agricultural unemployment occurs.

Lamug (1983) argued that industry failed to generate the employment opportunities that are required for the transformation of a dominantly agricultural employment to one that is dominantly industrial and service-oriented. Industry failed to absorb an increasing proportion of the labor force, and it was likewise unable to reverse the decline in labor productivity.

Here production growth rate grew from a positive value until the 37th year then become a negative value in the 50th year. The production grew until it reached the limit of growth. Limit productivity of production happened from the 23rd year. This was affected by the decreasing of soil fertility and other factors. As resource quality declined, the area was unable to sustain population growth. The population continued to grow, albeit at a slower rate. Incomes, however, typically rise rapidly. So in the latter stage, production falls as demand rises. The result is an extraordinary growth in imports at the last year of simulation.

The accelerated investment in equipment and machinery, accompanied by the rapid decrease in the agricultural labor force, made agriculture much more capital-intensive than before, but the average productivity of capital tended to decline and the costs of production to increase. This may be the reason why the



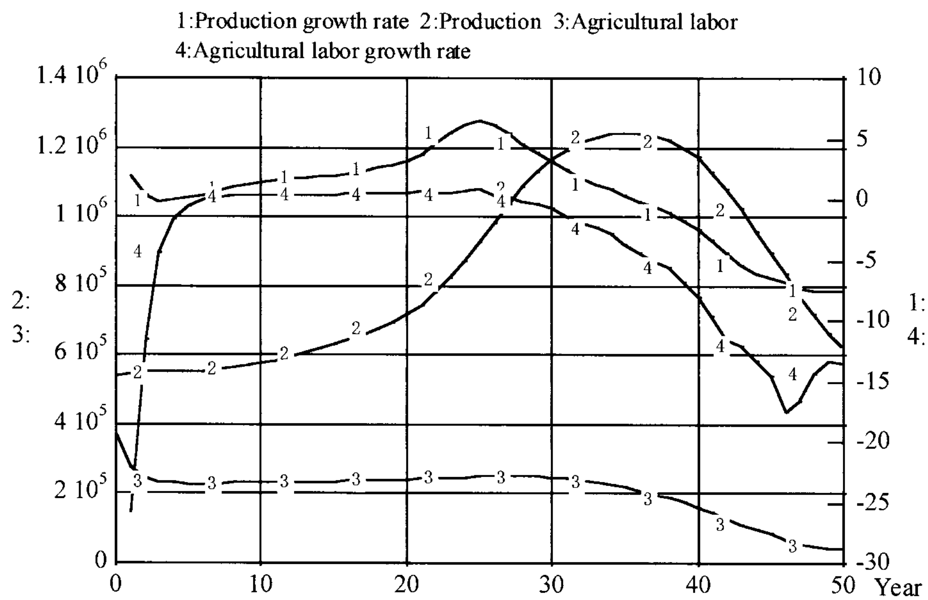


Figure 10. Case I: high farming system.

productivity of capital in farming has become generally unfavorable for farmers (Kamiya 1983).

Greater capital investment and more intensive use of land in agriculture increased agricultural output in the short-term but in the long-term destroyed the productivity of vast land areas by erosion and salt contamination (Forrester 1973).

Indonesia experienced the Green Revolution using modern agriculture technologies where rice output doubled between 1970 and 1984, but it has remained stationary since then. Moreover, between 1986 and 1988 grain production actually fell by 14 percent (Redclift 1990).

These technological developments have been designed specifically to reduce the importance of nature in rural production. To this may be added the substantial reduction in the numbers of individuals working in agriculture, with technological change on the farm being dominated by process rather than product innovations, and associated with increasing employment in the agricultural supply industries. Modern farming methods have lost much of the public's confidence and political support (Munton et al. 1990).

Case II—Sustainable Agriculture

In this simulation, as in the Case I—High Farming, we employ two figures with the same variables from the base run simulation for the upper figure, except for the production variable (Figure 11). Production increased until the 50th year of simulation. Support from government in the spending policy such as developed by Keynesian Economist, is needed for the first 20-30 years. If this policy is applied then the economy can takeoff, and in turn a self-standing and autonomous economy will be gained. A sustainable agriculture model is expensive, but still better than high farming. Because the program will be complex and site-specific, results may be slow to be realized and difficult to assess. Governments will need to be patient and persistent in their efforts if they want to use this program.

For sustaining agriculture, deregulation in the form of a multiplier and an adaptive system construction was needed from the 30th year. This period decrease in agricultural labor can be seen in the lower figure. In the early years of the simulation, agricultural labor increased positively and then moved toward equilibrium until the 26th year, but after that it moved toward a negative value. The reason for negative growth of agricultural labor and agricultural labor growth rate is the same as that found in Case I, industry started to grow.

The lower figure also shows that production growth rate and agricultural labor growth rate declined steeply in the early years and then followed a growth pattern similar to agricultural labor. Of special note in this figure is that production growth stablizes growth and does not reach a negative value. This sustainable case does not need a high growth rate of production and agricultural labor.

The purpose of sustainable agriculture is different for high farming or conventional farming. High farming can be constructed quickly with a high investment but it is very dangerous. Intensive or conventional farming systems which use high levels of synthetic fertilizer and pesticides are generally viewed as the least

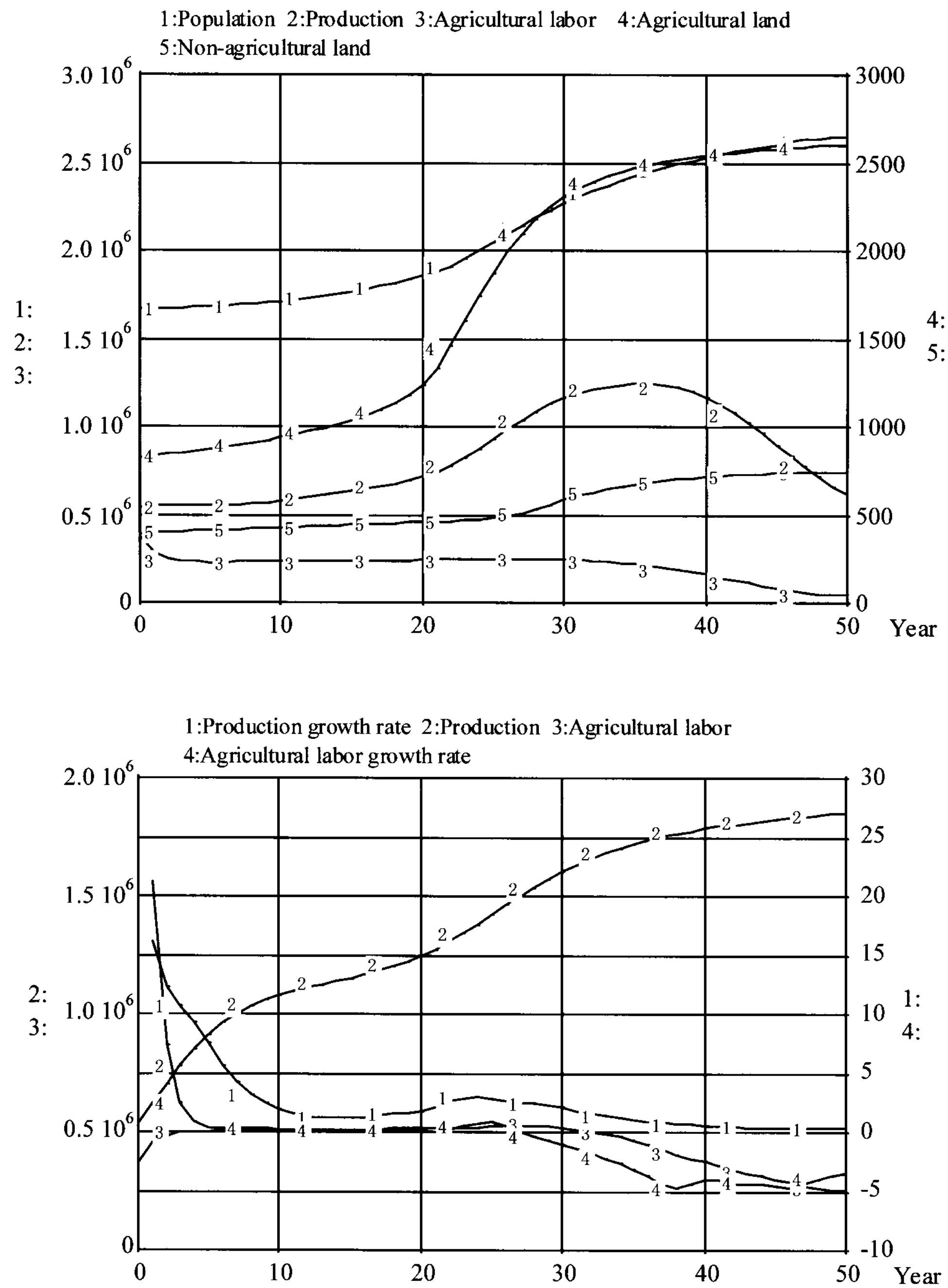


Figure 11. Case II: sustainable agriculture.

sustainable, and one response to this perceived problem has been the development of integrated farming systems (Tait & Morris 2000). Environmental degradation occurred from the Green Revolution using high farming (Clay et al. 1994). In some instances, capital-intensive technologies displace workers. Thus, the sustainability of this strategy is now in doubt (Hazell & Garret 1996). Because of this effect, farmers are likely to hold onto traditional farming techniques suited to local ecologies and to the circumstances of ordinary resource-poor farmers (Paarlberg 1994).

Conclusions

This study allow us to understand and explain the complex behavior of a particular type of sustainable agriculture, influenced by population growth through transmigration which is confronted with different decision horizons.

The model demonstrates the ways to develop a requisite model of sustainable agriculture using the system dynamic approach tentative parameters of Southeast Sulawesi Province. We conclude that this control strategy is feasible but that further work is needed for its implementation.

We want to emphasize that we have not yet built a real prototype of the system described by this model. Therefore, the current applicability of the model presented here is limited by lack of real data for calibration and validation. The work we are reporting here is a feasibility study of controlling the population, land, production, and labor modeling perspective. The results indicate that this is feasible using measurements of sustainable agriculture, and estimates of population increase and land availability. One should not expect models of the kind discussed in this study to predict the exact form and timing of future events. Instead, the model should be used to indicate the direction in which the behavior would alter if certain changes were made in the system structure and policies. Therefore, the model runs should not be taken as predicting the year in which a condition of real population and production will occur.

The values used for these variables are hypothetical and would need to be more realistically selected in future work. The control model did not include other technology level, live quality condition, and social condition variables which would likely affect the selection of the set point. In a future work, we plan to address issues that limit current applicability of the model, generate real data for calibration and validation, extend controls to long-term behavior, and include other limiting factors and processes.

The need to increase food production to meet the expanding needs of the population will put enormous pressure on all natural resources, including land. The long-term solution can only come from better domestic policies that result in higher agricultural production, higher economic growth, and lower population growth. Well-planned, long-term national and regional land conservation and rehabilitation programs, with strong political support and adequate funding are needed. Nevertheless, the results demonstrated the general trend of sustainable agriculture in regional areas of Southeast Sulawesi-Indonesia.

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