THE INCORPORATION OF LAND SYSTEM CONCEPT INTO AGRICULTURAL DEVELOPMENT MODELS

Tejoyuwono Notohadiprawiro

Introduction

An agricultural development models is constructed to help policy makers understand the complexity of agricultural development and select among the several options the most operational policy. This should be based on the cognitive interrelationship mong the policy variables and their consequences upon the agricultural development process. The model is also indicate crucial policy issues in the coming decades and to recommed options for policy actions to address those crucial issues.

The Indonesian Agricultural Models (INAM) is one of those models presently operating or under construction in many parts of the world. Athe existing models are typically socioeconomic and sociopolitical modules. When agronomy is included as aone of the modules, it is treated mainly as biological phenomenon produced by a so-called sterilized envirorment. In suvh an environment life performances are presumed controllable by adding, remofing or modifying imaginary factors along mathematical pathways. It is true that forecasting and predicting become so much easier. But as the data base is remote from reality, the predictive capability of the model may be weakened considerability. Although inherently models are theoritical devices, they must remin abstractions of realities in order to be effective in supporting policy formulations. Unless this is kept in mind policies will not be operational.

Diversity of Indonesian Agriculture

The diversity of the Indonesian agriculture poses many difficulties for the designing and the implementing of agricultural policies. The biophysical or agroecological environment of the Indonesian Archipelago is indeed diversed. As the technological inputs in farming are mostly limited, farmers have been adapting their

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farming systems to local conditions for sustainability. The multitude of tradition is the other factor of diversity.

The climate ranges from hot tropical monsoon in the lowlands to temperate-like in the highlands. In the high altitude areas of the Jaya Wijaya Mountain Range of Irian Jaya there are even an almost perpetual snow cover. The west and northwest are wet, while the southeast is semiarid. The soils are consequently also diversified. About one quarter of the land area is swampy which a large part of it consists of peat. Another quarter is covered by strongly leached, very poor soils, and sandy soils of almost pure quartz. There are large areas of young, light and potentially fertile soils from volcanic ash, in contrast to extensive areas of very heavy and swelling clay soils. A great portion of the red soils are of the variable charge type. They require different treatments than those which are of the permanent charge type (Sanchez, 1976; Fox, 1980; Uehara & Gillman, 1981). The lithology is quite variable, from acid to ultra basic. The stratigraphy ranges from as old as pretertiary to as young as holocene. Topography varies considerably, comprising at the one extreme flat plains and depressions and at the other mountainous areas and depositions, while in the latter landslides and erosion are prevailing.

The quite variable distribution of farm size is another fact which add to the diversity of Indonesian’s agriculture. According to the BPS Agricultural Census of 1973 the average size of all farm types by provinces ranges from 0.54 ha in the Special Province of Yogyakarta to 5.23 ha in the Province of Central Kalimantan. The range in each major island or island group is as follows: 0.81 ha in West Sumatera to 2.55 ha in Riau, Java 0.53 ha in Yogyakarta to 0.94 ha in Jakarta, Kalimantan 1.05 ha in South Kalimantan to 5.23 ha in Central Kalimantan, Sulawesi 1.14 ha in South Sulawesi to 2.14 ha in Central Sulawesi. The Southeastern Island Group 0.87 ha in Bali to 1.79 ha in East Nusa Tenggara, and the average in Maluku Province is 2.17 ha.

The average size of agricultural estates by provinces ranges from 118 ha in Central Sulawesi to 3,932 ha in Lampung. In the different islands the ranges are: Sumatera 243 ha (Riau) to 3,932 ha (Lampung), Java 748 ha (Central Java) to 1,114 ha (Yogyakarta), Kalimantan 394 ha (West Kalimantan) to 1,116 ha (South Kalimantan), Sulawesi 118 ha (Central Sulawesi) to 1,153 ha (South Sulawesi), The Southeastern
Island Group 177 ha (East Nusa Tenggara) to 540 ha (West Nusa Tenggara), and an average of 420 ha in the Maluku Province (Woelke, 1978).

The smallness of the landholdings is a major factor of the inconduciveness of the Indonesian farms in general to intensification programmes. Programmes which are usually successful for large farms may not be so when applied to small farms. In large, commercial farms the main objective of inputs is increasing productivity with a built-in risk compensation mechanism of carried-over profit from one planting season to the other. In small, subsistent farms the main objective of inputs is alleviating risk of production. There is no surplus of produce that can be carried over to compensate for future risks. Each planting season stands by itself, so that it must be self-sufficient.

**Land Systems As Natural Production Units**

Considering the spatial diversity of Indonesia’s agriculture which basically stems from the diversity in landscape, the incorporation of the land system concept into the INAM is standing to reason. The resulting geographical model has been proved useful when land as a natural resource is fundamentally involved in the production process (Notohadiprawiro, 1982; Notohadiprawiro *et al.*, 1982; Notohadiprawiro & Sukana, 1982; Notohadiprawiro *et al.*, 1983).

Agriculture is a culturally subsidized solar system (Jansson & Zucchetto, 1978). Due to the ever increasing demand for higher yields and more diversified produces, the culture subsidy is increasing with an alarming rate ever since. Agriculture today is going to join the group of energy consuming of industries. This is the opposite of what it should be as essentially an industry producing energy through fixation of solar energy by crops (Anon., 1980). The basic idea underlaying the saving of expensive inputs in agriculture is to make plants to function effectively as an intermediate active pool within the natural mechanism of exchange of energy and matter. Plants intercept a part of the flow of energy and matter from the atmosphere to the lithosphere. They also take part of the transformation and translocation processes of energy and matter that take place within the uppermost weatheriong zone of the lithosphere. As plants, after domestications, are the elemental unit of a farming system, their effective functioning calls for a farming system which is adapted to the specific characteristics of the physical environment. This the
central concept of the land system approach to agricultural development and its operation is simulated by geographical model. Fig. 1 shows the categories of inputs that define performance. The land system approach deals with the regional effect on the assumption that

A satisfactory regional effect—and part of the temporal effect (season)—are obtainable through adaptation. This in turn means diminishing risk and it may save managerial and/or technological inputs. Development policies become compatible with the needs and demands of the peasantry which make up the major portion of Indonesians agricultural community.

Traditional farming is one of low technological input so that it is fundamentally sustained by adaptation to the natural environment. Therefore, certain cropping pattern or farming system is apt to found in one land system than in another. The understanding of the long established relationship between certain land systems and certain cropping patterns or farming systems is basic to defining land development alternatives the array of possible policy options.

Experience from African development countries, for instance, have revealed that increasing technical inputsto farming does not necessarily lead to a more intensive use of the land (ORSTOM, personal communication). People tend to cultivate more land, spreading out the additional inputs instead of using them for intensification of their existing farming systems. This shows that supplying more input to traditional farms may not result in the consolidation of land holdings.

**A land system defined**

A land system can be envisaged as a natural processing unit of energy and matter, consisting of a compensatory combinations of storage and active pools its distinctive existence among other land systems s maintained by its specific internal flow patterns and external interchange processes of energy and matter. A land system may be composed of similar sites, or of recurring distribution pattern of different sites. It is a functional land individual of the population of lands, so that using the land systems approach the
determination of similarities or dissimilarities among land parcels can be consistently applied throughout the country. This means better nationwide policies, programming, assessment and monitoring.

A land system may also be defined as a gross land pattern formed by the recurrence of similar sites or site sequences within a finite area, where the sites are defined on partial interdependence and intercorrelation of several attributes. Where a steady state of dynamic equilibrium is approached, there is almost complete interdependence and intercorrelation of attributes and all components of the land are mutually adjusted. This is the case in regions with homogeneous rock, climate and relief (Ruxton, 1968). Mutual adjustment of land components is the evidence of maturity, while otherwise the land is young or incipient.

Land parameters are factors determining the regional effect and part of the temporal effect (season) on crop performance. Each factor has several expressions as agent of processes, as capability criteria, or as conditioning elements. The factors and their respective expressions are:

<table>
<thead>
<tr>
<th>Climate : (considering altitude)</th>
<th>Soil water balance (defined by soil moisture dynamic and slope)</th>
<th>Characterize season and weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Radiant energy (usually measured by day length; might be related to air temperature)</td>
<td>• Soil water balance (defined by soil moisture dynamic and slope)</td>
<td></td>
</tr>
<tr>
<td>• Heat balance (usually measured by air temperature; in tropics air temperature can be correlated to altitude using Oldeman’s equation $T = 27.09 - 0.005729 \times A$ where $T$ is the average annual air temperature in °C and $A$ is altitude in meters)</td>
<td>• Soil temperature</td>
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<tr>
<td>• Atmospheric water balance (balance between rainfall and potential evapotranspiration; called also effective rainfall)</td>
<td>• Soil fertility (nutrient availability and storage)</td>
<td></td>
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<tr>
<td>• Wind (if detrimental)</td>
<td>• Stability of quality and quantity (susceptibility to erosion)</td>
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Lithology:  
- Mineralogy (nutrient reserve and release; mineral weatherability)
- Subsurface water dynamic (leaching, internal drainage, nutrient supply from ground water)
- Stability (susceptibility to mass waste)

Biology:  
- Soil biology (organic cycle)
- Pests and diseases
- Weeds

 Alone or in specific combinations the factorial expressions from habitat determining regimes. A regime is an indication of a certain site quality determining condition. Land systems are differentiated by the following regimes:

PHOTOSYNTHETIC ENERGY REGIME, determined by radiant energy

MOISTURE REGIME, determined by:  
- atmospheric water balance
- soil water balance
- subsurface water dynamic

NUTRIEN REGIM, determined by:  
- soil fertility
- mineralogy
- soil biology
- subsurface water dynamic

THERMAL REGIME, determined by:  
- air temperature
- soil temperature

RISK REGIME  
- physical, determined by:  
  - soilscape stability
  - lithology stability
  - wind

- biological, determined by:  
  - pests and diseases
  - weeds

These regime are closely interrelated and interdependent in a mutually compensative fashion. Long time experience has pointed out that drought and floods, and low soil fertility are the most important yield affecting factors in Indonesia. therefore,
moisture and nutrient regimes should be the differentia of major land systems. Less important are photosynthetic energy and thermal regimes because they are restricted to zoning by altitude. They are placed as second order differentia. Next in hierarchical order comes the physical risk regime. The biological risk regime is in fact not an inherent property of land. It is a crop management criterion and as such it can be excluded from the land system differentiae.

In tropical monsoon climates like Indonesia, there are no seasonal changes in temperature. Temperature is related to altitude as it might be true also with radiant energy. Most of the rains in Indonesia are orographic so that in general cloudiness increases with altitude. Since solar radiation decreases with increasing cloudiness, solar radiation is negatively correlated with altitude. There are to a certain degree seasonal variations in radiant energy, but these are already implicitly covered by the moisture regime differentia, since season are the reflexions of the temporal changes in moisture regime.

A land system is not formed by the more coexistence of land attributes. It is a real system integrating all fundamental component of a habitat. It is a practical natural unit to serve the two basic purposes of the study of biological production system:

1. To understand the overall natural environmental control over crop performance, how this controlling mechanism affects the input effect, and what should be the compensatory treatments for optimizing production, if need be
2. To acquire the most useful basis for the spatial dissemination of results, which otherwise will be no more than isolated pieces of evidence

Land systems can be easily identified in the field, or from aerial photos, as many of their parameters are readily recognizable, like soils, landform and drainage conditions, or their reflexions such as the composition of the natural vegetation which reflects the climatic regime, the associated landform of a certain type of lithology, etc.

In the INAM context a land system is defined according to its physical characteristics as major differentiae. In the Indonesia situation, cropping patterns or farming systems and size of landholdings tend to conform or relate to site condition. The form and extent of agricultural landuse are implicated in the physical attributes of land systems. This site-dependence of the Indonesian agriculture is likely to remain so the
many years to come, notwithstanding the massive efforts in putting intensification programmes on the ground. It has been said previously that the biggest constraint is the smallness of the landholdings. One may conclude that land system by the proposed definition are valid units of biological production.

**Regionalization by Land System**

The yield of crops is the result of the photosynthetic function of plants. This function is governed by two groups of factors. One group is exogenous, consisting of various inputs. There are the natural inputs coming from the land system and the cultural inputs of anthropogenic subsidies and interventions. The other group is endogenous, comprising the plant genetics. In the INAM the natural inputs were worked out to form the physical Environment Submodule (PES). The cultural input and the endogenous factors were built into the Agronomy Submodule (AS). The two submodule are then linked to form the Agroecology Module (AM).

The PES is presented in Fig. 2. This model is used to guide the computation of the moisture regime (MR), nutrient regime (NR), thermal regime (TR) and erosion regime (ER). Erosion is to represent total risk on account of its widespread occurrence in agricultural lands. Tentatively the photosynthetic energy regime is accommodated within the MR and TR. MR, NR and TR define the potential productivity of an area, while ER defines the potential risk using the area. Potential productivity and risk are the criteria for land systems delineation and classification.

Land evaluation for capability classification needs to consider the average farmer’s perception of the value land. How would be the conditions of the land that an average farmer is familiar to that kind of land? This means that given that land a farmer with an average skill will by himself succeed with great probability in managing it. This is the central concept of land suitability. The more land attribute are unfamiliar to the average farmer, meaning the shorter he becomes of skills and experience, so that the more outside help he needs, the less suitable the land is. The land becomes unsuitable if one of the attributes and only that is beyond amendment due to technical impossibility or economically unjustified or socially incompatible.
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This is a dynamic approach to land evaluation since the average skill can be improved, or technical, economic or social constraints can be alleviated. Due to the strong social aspect of the system of land evaluation an input from the Social Module into the PES is essential. A dynamic approach has several advantages over the commonly accepted standardized procedures. These are:

1. The definition of land suitability clearly reflects the condition of balance between need or want and available means of satisfaction
2. The class criteria imply all major factors determining the available means of satisfaction:
   - technology (science) measure technical accessibility of obtainable reserves
   - resources (supplied by nature)
   - possibilities (personal ability) conditioned by social structure, economy, policies, politics, etc.
   - entitlement (social position)
   - chance (defined by environment)
3. Its space and time related classes of suitability offer better comprehension of the full range of policy options

Standardized procedures using rigid class differentiae are developed on the basis of the technical accessibility of obtainable reserves. The assessment is made on an assumed optimum possibility, entitlement and chance from the point of view of advanced economy and conservation of resources. These are especially true with acquired systems of evaluation and classification from highly developed countries. Efficient production is the result of interaction of technology – resource – management. A different resources needs different technology and management. The abundance of certain kind of resource or the predominance of a certain condition of a resource will strongly affect value judgements and impact statements concerning the whole system of resources. For
example, a slope is the same reality everywhere, but it is a different fact in say Belgium and Indonesia. A fact is a reality attached to a certain setting of phenomena within the scope a definite target information system.

A philosophy generated by a certain perception of certain realities cannot be imported by countries with different realities and different perception of these realities. It will make no sense to apply for instance the US system of land capability classification to Indonesian conditions, especially when the result will be used to formulate agricultural development policies.

**Class Criteria of Regimes**

Moisture regimes are classified according to the soil moisture producing characteristics of land:

1. Precipitation (rainfall) and potential evapotranspiration. The difference of P and Eto is an index of soil moisture replenishment or length of growing period for rainfed crops.
2. Relief and surface retention. These are the capacity factors of rain water conversion to soil moisture. Surface retention creates a time-lag in the conversion process. Runoff reduces the amount of convertible rain water, while oppositely runon increases it. An excessive runoff makes the site drier than what the rainfall normally implicates. A high runon develops a wetter condition than normal.
3. Moisture storage capacity of the soil profile. It is indicated by the infiltration and percolation rates, and the water holding capacity of the soil (determined collectively by the soil moisture dynamics and the soil effective depth).

Nutrient regimes are determined by:

1. The balance between the eluvial and anti-eluvial process acting within the solum.
2. The mineralogical composition of the soil, in particular its content of weatherable minerals.
3. The mineral reserve in the soil parent material (collectively determined by mineral content and thickness of parent material).
Anti-eluvial processes are those which retard or reserve eluviation. They bring about the retranslocation of matter from the lower to the upper part of the solum and eventually into the rooting zone. Anti-eluvial processes are evident from:

1. The accumulation of organic matter in the topsoil. Its degree is morphologically identifiable by the prominence and thickness of the horizon.
2. The periodic or seasonal return of soil solutes to the topsoil by the ascending capillary flow of soil moisture in dry periods or during the dry season (salt efflorescences).
3. Soil profile homogenization by the self-churning process of swelling clay soils.
4. Faunal pedoturbation leading to horizon mixing (haploidization).

Tentative thermal regimes are identified by air temperatures approximated from altitude using Oldeman’s equation. Contour maps are used as base maps for the delineation of thermal regimes. It is also used to interpret the part played by the capacity factor relief in determining the moisture regime. It serves in conjunction with the isoerodent maps the subdivision of land systems in terms of erosion risk and the need for conservation measures.

Wherever it is appropriate, special conditions which create special use problems, or may exclude agricultural use, are added to the land systems differentiae. These are:

1. Thick, fibric peat.
2. Need of special drainage techniques, or impractical to apply drainage.
3. Hazard of emergence of acid sulphate material.
4. Almost pure quartz deposits.
5. Special soil fertility problems such as related to ultrabasic parent material.

**Land Suitability Criteria**

A suitable land should meet the following condition:

1. The moisture regime indicates the possibility of having at least two rainfed crops a year, whether sawah rice or upland food crops, or a combination of them. Drier MR may be included in the suitable class if traditional technology is available to develop supplemental irrigation (the subak of Bali or the dharmatirta of Java).
2. If sawah rice is part of the cropping pattern, the maximum permissible slope is 15%. If only upland food crops are possible, the maximum permissible slope is lowered to 8%. For perennials it is 15%.

3. The effective soil depth should be not less than 50 cm for sawah rice and annual upland crops, and more than 50 cm for perennial crops.

4. Soil texture is loamy to clayey, pH is 4.5 to 7.5, EC reading is less than 2 mS, ad no indications of intensive gleization.

5. Thickness of the A horizon is more than 30 cm, or the average content of organic matter throughout the solum is enough so that the need for N fertilizer is only supplemental.

6. The sand fraction is composed of felsic and mafic minerals without predominance of any of them, and only at the most a subordinate content of quartz, suggesting an intermediate or basic parent rock.

7. No soil fertility stresses and no conditions which create special use problems.

8. The average annual air temperature is above 21°C (below 1,000 m altitude).

The less suitable lands are divided into three classes:

1. Class 1: 10-20% of the total number of criteria are outside the suitable limit, but still manageable.

2. Class 2: Ditto 20-50%.

3. Class 3: Ditto more than 50%.

Each class is further subdivided according to the criteria not satisfying the definition of suitable. This is to indicate what kinds of inputs are needed.

The criteria of less suitability are as follows:

1. The moisture regime indicates that at the most only one rainfed crop per year can be obtained with good chances.

2. For sawah rice or perennial crops the slope is 15-45%, and for annual food crops it is 8-30%.

3. Effective soil depth is less than 50 cm but not less than 20 cm for sawah rice or annual food crops, and 30-50 cm for perennial crops.
4. Soil texture is sandy, pH 3.5-4.5 or 7.5-8.5, EC is 2-4 mS, and moderate to strong gleization.

5. Thickness of the A horizon is 30 cm or less, or the average content of organic matter in the solum cannot support a reasonable crop without complementary or full application of N fertilizer.

6. The sand fraction is predominantly felsic in mineral composition with a moderate admixture of quartz, suggesting an acid parent rock.

7. Manageable soil fertility stresses, but no conditions of special use problems.

8. The average annual air temperature is less than 20°C but not less than 18°C (not higher than 1,500 m).

If one of the land properties and only that is outside the less suitable range and he suitable range as well, the land is rated unsuitable.

**Some Comments About Geographical Models**

The main weakness of a geographical model in systems analysis is that it cannot predict the effect of small, indiscrete changes in the yield determining characteristics of the environment. In such a model changes are not registered as consecutive points, but as a series of groups of points or areas. Implicitly this means that a change will be recorded as a change only when it exceeds a certain predetermined critical value. Thus the variables are treated as being discrete and consequently their progression goes on stepwise.

A geographical model, however, has the apparent advantage over a pure mathematical model that it:

1. Is much simpler to construct and to operate
2. Needs no detailed knowledge about the quantitative effect of a growth factor on the yield of a crop
3. Can generate useful information about the functional relationship of crop performance to environmental conditions using a limited data base
4. Simultaneously incorporates the principle of regionalization as the central concept of land use planning
This geographical model of land systems is derived from the comparative-geographical method in soil research as described by Rode (1978). The construction and operation of the model is much simpler as it uses the ordinary cartographic techniques. The model can perform adequately on a limited data base, since all pertinent variables cannot have values outside the confinement set by each particular land system.

In addressing policy issues there will be no need for elaborating on how every measurable change in the value of a certain land variable should be accommodate with a new policy. A change in policy is appropriate only when the total change in the values of the land variables exceeds a preselected permissible limit. This critical interval of change before a new policy must be formulated is contained in the geographical differentiae of land systems. Although geographical models are not for theoretical simulations, their practical value is high. As policies are concerned with pragmatism, the applicability of a simulation model to follow the bearings of different geographical settings of lands upon human interests is most important. It is the holistic approach to factual realities that makes policies operational statements.

References


