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ABSTRACT

A bay system includes the shore and adjacent sea as well as the watershed that rains water into them. This is a planning area or concept where resource allocation could be done systematically for economic advantage of all stakeholders and for sustainable environment.

One of the problems in the bay is pollution due to overland flow from upstream. The pollution renders the water in the adjacent sea unfit for modern technology such as cage culture of valuable fishes and decreases the marine pollution, which are sources of livelihood for most if not all of the people living in the coastal area. Another problem is in the bay system itself, which is the competing land uses that, in turn, may most likely be conducive to the pollution problem. Usually there is a management authority in the bay but it focuses on resource use planning particularly in the shore and adjacent sea but not including the watershed that contributes to the pollution problem. The issue to be resolved is the wise use of resources in the bay system or the resource allocation in such system. Optimum resource allocation requires linear programming for the bay system which is the main concept of this paper. Linear programming is not limited only in use in businesses but could also be applied in natural resource allocation such as in the bay system. There are many bay systems in Western Visayas needing optimum resource allocation. We have to allocate our resources well to the growing population of the country and the bay systems are among these important resources; simply saying that linear programming in this context is indispensable.

The linear programming is a mathematical and operations-research technique, used in administrative and economic planning to maximize the linear functions of a large number of variables, subject to certain constraints. The development of high-speed electronic computers and data-processing techniques has brought about many recent advances in linear programming, and the technique is now widely used in industrial and military operations.

Linear programming is basically used to find a set of values, chosen from a prescribed set of numbers that will maximize or minimize a given polynomial form. The polynomial is linear.

This technique could be used in determining the extent of resources uses in Bay System. This will involve finding the appropriate parameter/s for the formulation and solution of linear inequalities and equalities. Thus, the resource uses in the Bay System could be optimized for the benefit of the people and other stakeholders and also the environment.

I. Introduction

Western Visayas is a region which is composed of provinces located in three islands of Panay, Guimaras, and Negros. These provinces are Aklan, Capiz, Antique, Iloilo, Guimaras and Negros Occidental. The region has a total land area of 2,022,311 ha with a population of 6,208,733 (as of 2000 census). Its growth rate is 1.56 % per annum. Despite

its labor force of 4,589,000 the participation is rate is 69.1 % meaning a non-participation rate of 30.9 % which is still considerable. It is one of the regions in the country with the longest coastline and many people reside along the bays. Most of them subsist on marine resources both flora and fauna.

Farther from the coast are agricultural and timber lands in many areas of the region. These constitute the bay system. It includes all the lands that drain to the coasts. Because of the erosion that proceeds to the coasts, the concept of the bay system came into being. Such erosion is hazardous to the coastal resources and is prevailing in most bays in Western Visayas.

The people living in the bay systems in the region are mostly poverty-stricken. With considerable unemployment rate, the people in the bay systems overexploit the resources from the forest lands, uplands, lowlands, mangroves and even the fish populations in the immediate seas are no longer at a sustainable level. The resource uses are no longer ecologically sound.

With the advent of many technologies for livelihood and even industries the resources in the bay systems could be made ecologically sound, economically viable, socially acceptable and technically feasible. It is imperative, however, to first know the bio-physical and chemical properties of the different resources in the bay system in order to address the technical feasibilities of the various technologies. As long as there are feasibility studies specific for each bay system, the economic viability of these technologies could be confirmed and social acceptability may follow. The integrated resource management systems such as agroforestry, silviorchard, multiple cropping with soil and water conservation, pasture management with hedgerows of fast-growing leguminous species and aqua-silviculture are all ecologically sound and again, their economic viability and social acceptability needs first to be precisely assessed but will most likely be possible with specific technologies in certain bay systems.

The planning of resource use allocation in bay systems is an indispensable task especially today that we have high population and overexploitation of resources which our brothers and sisters have to do in order to eke out a living. We need to maximize income of the population in bay systems without sacrificing the environment and manage the resources at sustainable level. Maximizing income could be achieved by having basic information on the economic feasibility of ecologically sound, technically feasible and socially acceptable technologies. Then, linear programming technique could be performed to determine the

area for each resource use given information on constraints or the factors that would affect the allocation of resources. Today, with the advent of computer age, there are many software programs that could perform linear programming. One such software is GIPALS (General Interior-Point Algorithm Linear Solver) which could solve bulky linear programs with a limit of 15,000 variables and 15,000 constraints. The Microsoft Excel 2003 has also the linear solver that deals with solving linear models. With such facility, the linear programming for resource use allocation in bay systems could deal with specific variants of resource use technologies to the very detail.

The GIS (Geographic Information System) may be used in conjunction with linear programming for resource allocation in bay systems. The GIS could give the inputs as well as depict the outputs for the result of the linear model with now spatial dimension.

II. The Linear Model

The bay system includes all the land that drains water to the coasts. This starts from the highest topographic divide down to the bay. Resource allocation is basically the assignment of area for specific resource uses with non-negligible spatial dimension. It starts from protection forest which is fixed for areas with slopes greater than 50 % to production forest, upland production systems, lowland production systems and coastal technologies. The protection forest as a land use is deducted from the total area of the bay system and includes also the protected areas under the NIPAS (National Integrated Protected Area System) Act as well as marginal and degraded areas which are managed by the DENR and not profitable for resource use unless rehabilitated. The technically feasible and ecologically sound technologies are the subjects of the linear programming model in resource allocation. The linear model is to maximize income (net income) from the variables (hectares of resource uses) given the various constraints.

Thus, the linear model's objective function is:

Linear Model:

Maximize

$$\text{Income} = C_1L_1 + C_2L_2 + \dots + C_nL_n$$

Where L_i = ha of resource uses

C_i = average net income per year

Constraints:

1. ? $a_1 L_i \leq B_1$

Where: a_1 = number of households preferring the resource use most per ha

B_1 = Total number of households in the bay system

2. ? $a_2 L_i \leq B_2$

Where: a_2 = man-hours required per resource use per ha per year

B_2 = Total man-hours available per year

3. ? $a_3 L_i \leq B_3$

Where: a_3 = average gate price value of produce per resource use per ha per year in pesos

B_3 = Total market available in pesos in gate price equivalent

4. ? $a_4 L_i \leq B_4$

Where: a_4 = capital requirement per resource use per ha

B_4 = Total capital available from the population including seed money from government and other institutions

5. ? $L_j = B_5$

Where: L_j = ha of resource uses for production forest following the schemes of agroforestry, silviorchard, bamboos or pure production forest in taungya system with spaces in between utilized for cash crops with soil and water conservation measures such as contour canal. SALT (sloping agricultural land technology) or silvil-pasture may also be used.

B_5 = total area in ha with slopes 18-50 %

6. ? $L_k = B_6$

Where: L_k = ha of resource uses following upland integrated management schemes such as multiple cropping with soil and water conservation structures, silvi-pasture, coconut with trees or fruit trees in between, silvi-orchard, production forest with

taungya system.

B_6 = total area in ha with slopes 9 to < 18 %

7. ? $L_1 = B_7$

Where: L_1 = resource uses for the lowlands such as monocropping, polycropping, pasture, vegetable production, lowland rice, fresh water fishpond, tree plantation, orchard, poultry and livestock production in range or confinement, bamboos, coconut.

B_7 = total area with slopes 0 to < 9 %

8. ? $L_m = B_8$

Where: L_m = resource uses for existing saltwater fishponds such as different species of fish and salt production

B_8 = total area of existing fishponds and salt ponds

9. ? $L_o = B_9$

Where: L_o = aqua-silviculture resource uses

B_9 = total area required for mangroves and nipa

10. ? $L_p = B_{10}$

Where: L_p = monoculture coastal area resource uses in ha such as fish pens, fish caging, lobster culture, and mussel culture.

B_{10} = total area adaptable for the coastal area resource uses in ha

Another approach to the equality constraints is in terms of resource use units especially in cases where the soil varies too widely.

III. Possible Resource Uses

For Production Forests. The production forest may be either agroforestry through the taungya system or through alley cropping. The preferred species for the alley cropping are fast growing leguminous tree species planted in rows along the contour or across the slope. These species are:

1. Kakawate

2. Giant ipil-ipil
3. Rain tree

These species may also provide additional N nourishment to the intercrops by fixing nitrogen from the air because they have root nodules.

The other system of agroforestry is using non-leguminous tree species which are designed primarily for wood production. These are also planted along the contour and with additional SWC (soil and water conservation measure) such as contour canal or contour levee. The trees are planted in close spacing just above the contour canal. The possible species are:

1. Yemane
2. Mahogany
3. Eucalyptus spp.
4. Acacia spp.

Another agroforestry scheme is silviorchard or the interplanting of fruit trees with forest trees. The fast growing leguminous tree species to be interplanted usually provide for additional N to the soil. It is better to have SWC to be incorporated in this scheme. Bamboos may also be planted in taungya system where the spaces in between are planted to cash crops in multiple cropping scheme before the bamboos totally cover the spaces in between. The pure production forest may also be done using the taungya system where the spaces in between are planted with crops in multiple cropping before the trees cover the area with shade. In any case there should be SWC measure to supplement the scheme so that it would prevent erosion and conserve water. The SALT (sloping agricultural land technology) may also be implemented in long slopes.

The fruit trees may be the following:

1. Guava
2. Mango
3. Santol
4. Lanzones
5. Rambutan
6. Oranges
7. Babana
8. Banana
9. Avocado
10. Starapple

11. Chico
12. Calamansi
13. Atis
14. Marang
15. Coconut
16. Dalanghita
17. Dalandan
18. Macopa

The root crops may be the following:

1. Sweet potato
2. Cassava
3. Ginger
4. Yam
5. Peanut
6. Carrots
7. Potato

The root vegetables may include:

1. Gabi
2. Gabi china
3. Ubi
4. Radish
5. Onions

The fruit vegetables may include the following:

1. Beans
2. Mungo
3. Kadyos
4. Patola
5. Eggplant
6. Ampalaya
7. Squash
8. Upo
9. Okra
10. Tomato
11. Sili

The green leafy vegetables may include:

1. Pechay
2. Alugbati

3. Kangkong
4. Cabbage
5. Chinese cabbage
6. Malungay

The fiber crops that may be grown are:

1. Abaca
2. Native pineapple
3. Mulberry

The newly discovered crop is:

1. Jathropa

The ruminants may include:

1. Goat
2. Carabao
3. Cattle
4. Sheep

The poultry and livestock may include:

1. Native chicken
2. Layers
3. Broilers
4. Quail
5. Ducks
6. Geese
7. Turkey
8. Fattening swine
9. Breeding swine

The poultry and livestock are recommended in slopes $< 9\%$ and 9 to $< 18\%$. For multiple cropping, relay cropping may be followed or simultaneous planting of legumes and non-leguminous crops and vegetables. However, for slopes 9 to $< 18\%$, SWC measure is still recommended to be part of the integrated upland management scheme. In this slope, silviorchard, silvipasture, bamboos, coconut intercropped with fruit trees are still applicable. Note, however, that the gentler the slope the farther is the horizontal distance of the rows of SWC measures and the fast growing leguminous tree species. For each slope category the expenses and, therefore, the net income may still differ.

For lowlands with slopes $< 9\%$, among the recommended practices are lowland rice with relay cropping for rainfed areas but continuous cropping for irrigated areas. The results

of researches for lowland and upland agriculture are higher yield for semi-organic farming. Fresh water fishpond may also be practiced and in lakes and rivers, fish pens and fish caging may be considered as another resource use.

The species of fresh water fishes are:

1. Fresh water tilapia
2. Fresh water bangus
3. Shrimp
4. Carp
5. Hito

For the aqua-silviculture, an example of resource use is mudcrab production in mangrove and nipa areas. Others are fish production around nipa areas.

For existing fishponds, the species of fish to be raised may be:

1. Bangus
2. Seabass
3. Grouper
4. Tilapia

For other monoculture coastal resource uses, the following may be undertaken:

1. Oyster culture
2. Mussel culture
3. Seaweed culture
4. Fish caging
5. Lobster culture

IV. Sensitivity Analysis

The sensitivity analysis consists of ways to determine changes in the linear programming solution considering changes in variables and constraints. The Allowable Increase/Decrease is the change in the coefficient of the variable, L_i , in which the value of L_i will not change. The Reduced Cost is the amount by which the objective function coefficient for a variable needs to change before that variable will become non-zero. Because the LP (linear programming) model is maximization, the amount of change is amount of increase in the coefficient of the variable. For each constraint, the Shadow Price tells us exactly how much the objective function will change if we change the right-hand side (B_i) of the corresponding constraint within the limits given by the Allowable Increase/ Decrease.

V. Data Gathering

Bio-physical characteristics. The biophysical characteristics such as slope, soil, and existing resource uses are reflected in maps. The GIS may be utilized to provide input on the bio-physical characteristics or to display the bio-physical characteristics obtained from secondary data or primary data gathering in the field. It is important that the bio-physical characteristics of the bay system should be in detail especially as to area favorability to each set of resource uses. The bay system is divided in resource area units each with distinguishing set of bio-physical characteristics. This is achieved by overlaying of maps. The resource area units are described in detail with hectarage specified. The bio-physical characteristics may be used to determine area suitable and the management schemes needed for the profitable resource use.

Feasibility studies. The ecologically sound and technically feasible resource uses should be subjected to feasibility studies in order to determine the average net income per ha per year. The feasibility studies will also specify the production management schemes, man-hours required, products, demand and supply analysis, and income statement based on the gate prices of the products. The feasibility should include detailed market specifications for the products. Potential market survey may be done for each of the products and must be expressed in monetary terms. The total product market value per hectare per year must also be specified in the feasibility study. The feasibility studies must be made for each resource use.

Census. In order to gather information on resource use acceptable to the population (ha), man-hours and capital available, census of the household heads in the bay system should be done. Census means that all the household heads will be surveyed. The research instrument should specify the personal information of the household head, the household size, and other basic information about the household members, items on resource uses which are comprehensive and ecologically sound and technically feasible for the bay system. The preference/s of the household heads for the resource uses are obtained in ha.