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Integral Production Model for Small Farmers Based on Agroforestry Principles for the Yucatan Peninsula, Mexico

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Abstract

Monoculture is a highly productive cropping system in temperate zones, but ineffective under tropical conditions due to the rapid loss of nutrients from the soil and high competition between weeds and crops. It is an urgent task to test new technological and productive models more appropriate for small peasant farmers in the tropics of Mexico. This work aimed to assess a new agroforestry model proposed by researchers and local farmers as an alternative to improve the Production of Family Units (PFU) in the countryside of the Yucatan Peninsula in Mexico. It was confirmed that the model is adequate to capitalize the PFU if technological innovations can be adopted. The integral production model allowed a productive diversification of species such as: medicinal plants, basic grains, vegetables, fruit trees, wood for constructions, precious woods, firewood, milk, bovine, pork, eggs, and poultry, among others. Economically, the model proved to be able to satisfy the self-consumption needs of the PFU, but with important restrictions to satisfy the abroad market.

Subject Areas

Agricultural Engineering

Keywords

Production System, Farmer, Technology

1. Introduction

The agricultural development of the Yucatan Peninsula (YP) formed by the states of Campeche, Quintana Roo, and Yucatan in southeastern Mexico is a region where many agricultural programs have been launched based on the monocrop. The case of extensive cattle ranching and the production of henequen, corn, and rice monocrops in large extensions, present problems of low production and profitability.

However, there are agricultural development programs adapted to the tropics based on polycrops and agroforestry principles, adjusted to the socioeconomical small farmers' conditions with the following characteristics: 1). A moderate but sustained net production over time; 2). The diversity of species contributes to a better and balanced diet high in energy, proteins, and vitamins, as well as medicinal plants; 3). Optimal spatial use similar to the natural ecosystem with high ecological stability; 4). Closed nutrient cycle; 5). Employment and economic security during the year, since the crop and harvest cycles, are diverse; and 6). Socioeconomical stability of peasant families by not having to emigrate to urban areas for other jobs [1] [2] [3].

In the YP, the association of forestry and livestock species with annual, biannual, and perennial crops has traditionally been practiced by poor small peasants. This is the case of the milpa system inherited from the Mayan culture, the *solar* or backyards with mixed orchards being the core of the system. These productive strategies have been little considered when designing rural development programs in the region. This work aimed to analyse with a productive and economic perspective an agroforestry model as an alternative for small peasant farmers of the YP.

2. Materials

To propose the integral production model for peasant farmers, the following basic steps were considered [4] [5].

2.1. Community Selection

Different poor villages with predominant Family Production Units (FPUs) were first selected as ideal prospects models, feasible for future adoption.

2.2. Production Unit

The FPU was considered as the basic category of organization in which the capital, land, technology and workforce used for production were closely linked. The production unit consisted of a peasant family combining capital, land, technology and labor force for food self-sufficient purpose (milpa, beekeeping, backyard livestock, gathering, hunting, among others) and not for marketing.

2.3. Identificacion of Investment Levels

Three level of peasant investment were identified as: 1) **High**: more than 200

thousand pesos (10,000 usd); 2) **Intermediate**: 150 to 200 thousand pesos (7,500 - 10,000 usd); and 3) **Low:** less than 150 thousand pesos (less than 7,500 usd). Estructured interviewes to each UPF selected were carried out to collect information on production, land, capital, technology, food consumption, sales, production costs and labor employed. The FPU was selected according to the interviews and opinion of the community authorities.

3. Methods

3.1. Design of the Integrated Production Model

Based on the interviews, the subsystems and especific components of the FPU were identified as: Milpa maya by shifting cultivation based on corn and beans, fruit trees, livestock, forest management with enriched species. Upon identifying the components, the technical support group selected the most important innovation to be implemented as a model in the FPU of a cooperating small farmer. The model was proposed to the FPU participating members for final decision. Once the model was accepted, the community leaders disseminated it to the comunity [6].

3.2. Investment Analysis

An investment analysis was carried out using the methodology of the Economic Development Institute of the World Bank [7] with the purpose of determining the profitability of the investment. The analysis considered the principles of the "*refreshed cash flow*" analysis, placing the initial investment at the beginning of the projection and the residual value at the end.

The expression "*flow of funds*" was considered due to the importance of non-cash elements such as: domestic food consumption and payments in kind, which are very frequent and important in UPFC.

The investment analysis, besides helping to identify additional investments, it allows to foresee the extra labor requirements, input needs, increases or decreases in production. Likewise, it is feasible to do an ex-ante and ex-post analysis prior launching the proyect.

3.3. Price Update

Although the project was developed from 1990 to 1993, in this work the information was updated to 2021. The following formula was used to update prices:

$$\text{Value}_f = \text{Value}_i \times \frac{\text{CPI}_f}{\text{CPI}_i} \tag{1}$$

where:

$$\text{Value}_f = \text{Final value (2021)} \tag{2}$$

$$\text{Value}_i = \text{Initial value (1993)} \tag{3}$$

$$\text{CPI}_f = \text{Consumer Price Index 2021} \tag{4}$$

$$\text{CPI}_i = \text{Consumer Price Index 1993} \tag{5}$$

To obtain the Equivalent Values for the economic purchasing power between 1993 and 2021, the following CPI formula was used.

Example with 1 Mexican peso of 1993 updated to 2021:

$$\text{Valor}_{2021} = \text{Valor}_{1993} \times \frac{\text{IPC}_{2021}}{\text{IPC}_{1993}} = \$1 \times \frac{129.53}{15.31} \approx \$8.46$$

3.4. Dissemination and Training

Both dissemination and training were considered a strategic part of the project where researchers and participating producers exchange opinions. In the case of training, emphasis was put on the participating farmers who were capable of transmiting the new knowledge to other producers.

3.5. The Case Study

The case study analyzed especific elements of the model with very common interest among the participants [8].

4. Results

4.1. The Selected Community

The integral production model was located in the community of *D'zitnup*, in the state of Campeche Mexico located three kilometers from the municipaity of Hecelchakán.

Although corn production is one of the most important activities for the peasants, it is not an economic option. The very low production does not satisfy the family consumption needs so the emigration of young people to principal cities such as: Campeche, Ciudad del Carmen, Mérida and Cancún is the only way to collect money to survive.

4.2. Characteristics of the Selected Produccion Unit (UP)

With the purpose of making a comparison of the changes proposed for the UP, the economical analysis was made before starting the project. The information was obtained through interviewing the cooperating producer and the results are summarized in **Table 1**.

4.3. Proposed Innovations

After interviewing the cooperatin producer the proposed technological innovations were the next:

Corn. In the first two years of the project, the soil conservation tillage, the V-532 variety and fertilization with the formula 46-92-00 (N-P_2O_5-K_2O) were proposed. Starting the third year, an intensive use of soil was implemented by planting the hybrid H-509 in both the Spring-Summer, with auxiliary irrigation and the Autumn-Winter cycle with total irrigation. The weeds were controlled with pre-emergence herbicides and fertilitation with the formula 46-92-00 (N-P_2O_5-K_2O).

Table 1. Background of the Producction Unit.

Concept	Amount	Total
Land Use (ha)		**19.25**
Dry Spring-summer Cycle (Ha)		**2.04**
Corn	2.00	
Peanut	0.04	
Irrigation Autumn-winter Cycle (Ha)		**1.08**
Corn	0.04	
Tomatoes	1.00	
Other Vegetables	0.04	
Perennials (Ha)		**16.40**
Irrigation Fruit Trees	1.40	
Dry Forest Area	15.00	
Livestock Inventory (Number)		**22.00**
Pigs	2.00	
Piglets	7.00	
Poultry	13.00	
Working Days		**703.00**
Family Boss	300.00	
Son	300.00	
Salaried	103.00	
Farm Capital Assets ($)		**807002.15**
Secondary Vegetation Land	91979.00	
Agricultural Land	320827.00	
House and Pens	174046.46	
Equipment	67064.63	
Livestock	44673.08	
Inventory	108411.98	
Liabilities ($)		**133731.55**
Banrural Debts	65736.06	
SDR Debt	67995.49	
Net Worth ($)		**673270.60**

Fruit and vegetable garden. The traditional diversified orchard model was rescued with innovation consisted in microirrigation system, with new topological arrangements (10 mts distance each other) of species like: mango, chicozapote, cashew, avocado, mamey, nance and citrus. Between the alleys, nurceries and beds for vegetable production (radish, cilantro, beets, kohlrabi, lettuce, X'catic maya pepper, sweet and habanero peppers and tomatoes) were built [9].

Forest species. In the case of forest species, cedar, ramón as a local foder tree, and mahogany were planted in the surroundings of the orchard. Some of them were used as boundaries and fodder for cattle (Ramon) in the medium and long term and others for lumber in the long term (cedar and mahogany).

Cattle. It began with two cows, crosses of European breeds (Swiss-American 3/4, 1/8 Holstein and 1/8 Zebu) as dual purpose (milk and meat). Construction of a rustic pen was made and vaccination was a constant activity. The reproduction was controlled by hormones, and the inseminations were realized in predetermined period of time.

Pigs. A Landrace breed was introduced for the production of piglets and pigs for supply. The construction of a pen with local materials, cement floor, application of some vaccines against hog cholera and antibiotics, as well as the preparation of balanced food were some of the innovations.

4.4. Implementation of Innovations

Without the project, practically the farmer was not using 2.0 hectares of mechanized soils. After three years, an attempt was made to use those hectares.

Regarding the backyard, it was oriented toward livestock and the use of rustic pens was encouraged. In the case of pigs, it was not only important to confine the animals for productive purposes, but also to prevent health problems in the community, since the presence of *cysticercosis* can infect persons through pork consumption.

The capital of $275,967.00 was invested to aquire two pregnant cows, a sow for reproduction purposse, a grain mill and different fruit trees such as: mango, tangerine, avocado and banana rhizomes grafts. The construction of three rustic pens with local materials was also part of the investment. The producer contributed 16% out of the total investment, 53% of the investment was for the acquisition of the cattle (Table 2).

Without the project (YEAR 0), there was a deficit of more than 176 thousand pesos. This deficit increased by 235% due to the YEAR 1 investment, at the beginning of the project. The deficit decreased in YEAR 2 to only 25% in relation to YEAR 0. The profitability reached 100 thousand pesos and and 317 thousand

Table 2. Financial accounts of the model after four years of evaluation.

Concepts	NO PROJECT			WITH PROJECT	
	Year 0	Year 1	Year 2	Year 3	Year 4
Sales ($)	79192.00	63891.00	120962.00	205560.00	535789.00
Family Consumption ($)	11830.00	11830.00	101422.00	219464.00	189912.00
Invesments ($)	0.00	275967.00	0.00	0.00	0.00
Operating Costs ($)	267336.00	215681.00	267513.00	324355.00	408209.00
Income ($)	**−176314.00**	**−415927.00**	**−45129.00**	**100669.00**	**317492.00**

Note: YEAR 0 representing NO PROJECT and YEARS 1 to 4 WITH PROJECT.

pesos for YEARS 3 and 4 respectively. Regarding the balance sheet accounts (Table 3) the *assets* increased from $811,188.00 with NO project (YEAR 0) to $1,785,404.00 WITH the project (YEAR 4). There was a loan, for liabilities, from IDRC-Canada and went from $133,731.00 pesos to $265,702.00 pesos. However, with the proposed Production Model, it is feasible to capitalize family UPs by increasing the social capital from $697,181.00 to $1 528,705.00 (Table 3).

According to the results of the financial analysis with the methodology of the Institute for Economic Development of the World Bank, investing in the PU is more profitable when all components are analyzed as a whole. This methodology considers the different factors of production (water, soil, capital, technology and labor), as a unique component so the analysis results more efficient [10].

The integration concept is suggested by different authors [2], it implies the association of various elements in a harmonious way without harming each other. Such is the case of the Backyard Livestock, the orchard with species of different strata and the association of corn with velvet beans among other cases. The productivity of the different components increased through the years (Table 4).

When family production is oriented towards specialization, they are more vulnerable to the market. This was the case of a study with chickens, in Cambodia, where deaths were reported up to 27% [11] without having other production alternatives.

Another outstanding result was the biodiversity achieved with this strategy, in such a way that the producer managed around 65 species, of which 60 were plants and 5 animals. About 56% (36 species) out of the total 65 were encouraged and promoted thanks to the project.

Table 3. Accounting balance in Mexican pesos ($) of the production model.

Concepts	No Project	With Project
Assets	**811188.00**	**1785404.00**
Agriculture Land	320827.00	672618.00
Forest Area	91979.00	97301.00
House and Pens	174046.00	234869.00
Cattle	0.00	364890.00
Pigs	24320.00	201904.00
Poultry	15807.00	36489.00
Equipment	70305.00	116518.00
Inventory	113904.00	60819.00
Liabilities	**133731.00**	**265702.00**
Bank Debts	65736.00	17212.00
Debt to SDR	67995.00	35635.00
Debt to CIID-Canada	0.00	212855.00
Social Capital	**697181.00**	**1528705.00**

Table 4. Yields obtained in some component of the production model.

Producto	NO PROJECT			WITH PROYECT	
	Year 0	Year 1	Year 2	Year 3	Year 4
Corn ($t \cdot ha^{-1}$)	1.50	1.50	3.00	2.50	2.50
Beans ($t \cdot ha^{-1}$)	0.00	0.00	0.00	3.00	0.00
Pig Bellies in No.	2.00	2.00	2.00	1.00	2.00
Piglets in No.	9.00	9.00	9.00	12.00	20.00
Bovines in No.	0.00	2.00	4.00	5.00	5.00
Milk ($liters \cdot year^{-1}$)	0.00	0.00	1080.00	1080.00	1080.00

5. Discussion

According to the results of the financial analysis carried out with the methodology of the Economic Development Institute [7], the investment in the UPF is more profitable when components are considered as a whole instead of isolated pieces. The methodology considers different factors of production (water, soil, capital, technology and labor), highly needed in agricultural activities. The integration of these factors determines, at different scales, the efficiency process when affecting costs and performance of products from the primary sector [12].

With the proposed strategy, it is feasible to gradually capitalize the UPF's. On the other hand, more profitability was reached at the end of YEAR 4. This model applies mainly to producers with capital and land limitations, intending to satisfy their own consumption as a priority, rather than selling their products to the market [13] [14] [15]. In this sense, the simplest and most economical technologies, based on the improvement of the production units were the most accepted by farmers, such is the case of the mixed orchard [16], whose main characteristics are:

- Ecologically, it is an agricultural system very similar to a natural ecosystem due to its high diversity of species, high capacity to capture solar radiation, biological control mechanisms, closed nutrient cycles, efficient use of space, and a high degree of stability.
- Economically, it is a resilient agricultural system resisting fluctuations and insecurity in the market due to the different and multiple crops with different uses such as natural medicines, ornaments, wood, firewood, food, etc. In that case, the environment is well preserved.
- Distribution and demand for labor is in a staggered manner throughout the year avoiding labor concentration.
- It depends more on family labor.
- Very low economic investment, appropriate for poor farmers.

One of the most frequent difficulties in analyzing integrated production models is the evaluation of the results. In this case, the analysis techniques and methods used is one important contribution of this work.

6. Conclusion

Through the proposed family production model, it is feasible to improve the social capital in a period of four years. The integral production model in relation to a production system, based on monoculture, presents a labor demand in a staggered manner throughout the year which is mainly supplied by family labor and in this way, emigration can be diminished. Ecologically, it is a productive model that is more similar to natural ecosystems due to its high diversity of species, high capacity to capture solar radiation, biological control mechanisms, closed nutrient cycles, efficient use of space, and a high degree of stability. It is a multiple-use production model that favors the conservation of natural resources with different and valuable products such as: medicinal plants, basic grains, vegetables, fruit trees, wood for constructions, precious woods, firewood, non-timber products, and food. Economically, it is a resilient system capable of withstanding fluctuations and food insecurity.

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Conflicts of Interest

The authors declare no conflicts of interest.

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