

Technological Model and Sustainable Rural Development for Rainy-Spell Corn Producers in Mexico

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1. Introduction

Mexican agriculture presents problems that affect the producers, the rural society and the alimentary security. The first one has to do with the poverty of the field inhabitants. Data from the Consejo Nacional de Evaluación de la Política de Desarrollo Social (CONEVAL), indicate that by 2008, 44.2% of the population (47.2 million Mexicans) was poor, having at least one social lack and an insufficient income to acquire alimentary and non- alimentary goods considered basic. Out of the total of the poor population, 63.2% inhabit the rural and 36.8% the urban surrounding (CONEVAL, 2010). Poverty tends to worsen because the prices of foods have increased; at the beginning of 2008 the real prices of foods were 64% higher than those of 2002 and the index of food prices marked a maximum of 214.7 points in December of 2010 (Diouf, 2011).

The second problem refers to the climatic change of anthropogenic origin, since the total quantity of greenhouse effect gases (GEG) we send to the atmosphere is almost twice higher than the capacity of natural absorption. The rest accumulates causing higher temperature and abnormality in rain standards and annual distribution. It is considered that agriculture, forests and other uses of land, were the second most important sources of emissions of GEG to the atmosphere with a total of 131.56 MtCO_{2e}, accounting for 19% of the total emissions of the country (Diario Oficial de la Federación [DOF], Programa Especial de Cambio Climático, 2009). In the same way, agriculture is the activity most affected by climatic change and with it the different functions that it accomplishes: economic (production of foods and raw materials, productive linkages with other sectors), environmental (conservation of natural resources and biodiversity, ecological services,

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carbon capture), social (forms of social organization as the “mano vuelta”) and cultural (sense of bond to a social group).

The third problem relates to the low agricultural productivity of corn with mean national yields of 3,210 Kg ha⁻¹ which are far below of those gotten in The United States (9,450 Kg ha⁻¹) and Canada (8,510 Kg ha⁻¹) (Food and Agriculture Organization of the United Nations Statistical [FAOSTAT], 2010). To satisfy the internal demand 9.2 million tons of corn had to be imported spending almost 2,400 million pesos (Servicio de Información Agroalimentaria y Pesquera [SIAP], 2010).

The interactions of these three problems have become obstacles to attaining self-sufficiency in corn production and sustainable rural development. Corn is the main crop in Mexico, with an estimated harvest of 7.34 million hectares, 39.3% of the harvested total area (SIAP, 2010). This grain is Mexicans’ alimentary base with an annual consumption per capita between 120 and 130 Kg (Zahniser & Coyle, 2004). It is also an essential raw material of diverse productive chains: the industry of masa and tortilla, fritters, balanced foods, snacks and chemical industries that elaborate high fructose syrup, bioethanol, eatable oil, alcoholic drinks and lactic acid (Confederación Nacional de Productores Agrícolas de Maíz de México [CNPAMM] and Asociación Nacional de Empresas Comercializadoras de Productores del Campo [ANECPC], 2006). Likewise, corn is part of the memory of the Mesoamerican cultures, because it has contributed to the social organization; it has been creator of scientific and technological knowledge and it has given occasion for the biological diversity of this grain (Staller, 2010).

In the handling of corn, two contrasting trajectories or concrete models of solution of technological problems have interacted, concerning two paradigms or general approaches of investigation that define the outstanding technological problems and the necessary knowledge to solve them (Dosi, 1982).

The first trajectory, the modern one, is the hegemonic one and it is articulated to the “Productivist Paradigm” result of the “Green Revolution”. It prevails in the irrigated agriculture which occupies a fifth part of the total of harvested hectares. It is based on the use of high yield varieties which can achieve very superior crops to those of indigenous seeds, only if they are irrigated and fertilized. A greater fertility of ground and availability of humidity improve the ecology of weeds, plagues and diseases, thus making it necessary to introduce chemical products to combat weeds, insects and diseases (Borlaug & Dowsell, 2005). The entity prototype of this handling way is Sinaloa that contributes 51% of the total of the production of watering corn, with average yield of 10,180 Kg ha⁻¹ (SIAP, 2010).

The second trajectory or TM used in the handling of corn is the traditional or rural one that acquires an importance without precedents for the “Agro-ecologic Paradigm” (Altieri & Toledo, 2011). It prevails in general under rain-fed agriculture and, in particular, in federative entities with high indexes of poverty and specialization in corn production (Table 1).

These entities comprise 49.4% of the total of the harvested rain-fed area. Most are self-consumption producers living in extreme poverty, because their total revenue is insufficient to acquire basic foods and they have three or more social lacks (CONEVAL, 2010). They are also smallholders, because about 30% of their properties are less than one hectare size and a little more than 60% are between 1 and 2 hectares (Rascón et al., 2006). Likewise, they are low yield producers because they sow corn under extremely restrictive edafo-climatic and

States	Surface Harvested	%	Yield (t/ha)	Localization Coefficient ¹	Marginalization index
Chiapas	683,203	11.5	2.33	1.37	Very high
Guerrero	443,764	7.5	2.88	1.56	Very high
Hidalgo	190,596	3.2	1.32	1.21	High
Oaxaca	559,089	9.4	1.25	1.23	Very high
Puebla	506,113	8.5	1.64	1.70	High
Veracruz	551,295	9.3	2.37	1.12	High
Total	5,921,061	49.4	2.36	1.0	---

Source: Own elaboration with data from SIAP (2010) and from the Consejo Nacional de Población [CONAPO] (2006).

Table 1. Specialization in corn production and social marginalization in Federative entities of the Mexican Republic.

economic conditions. In order to be adapted to this adverse environment, they have re-created multiple agricultural systems that, in the last 60 years, have evolved because of a TM where modern and rural technologies interact. These millennial TM are at risk of disappearing because public policies excluded subsistence producers from the integral plans of agricultural development, implying that in order to survive, they have to diversify their activities. These plural activities, in turn, lead to intergenerational rupture of transmission of these cultivation methods, inappropriate handling of agrochemicals, greater damages to the environment and loss of sustainability of the agricultural activity.

In a context of low productivity, extreme rural poverty, climatic change, price rises of basic grains and application of erroneous policies to foment the productivity of rain-fed corn: are there technological options to promote productivity of corn producers in the framework of the sustainable rural development? In order to answer this question a study was carried out with a sample of 99 producers of Huaquechula Puebla, where a methodology was applied consisting of three stages: the impact of the technologies used in the handling of corn was evaluated; the high yield or efficient producers were identified, and the TM these producers used in the handling of corn was identified, which is intended to be transferred in order to foment the productivity and sustainability among the subsistence Mexican peasants that sow corn under rainy-spell conditions. Innovations have been the most powerful lever in the social evolution and it is achieved when new technologies are incorporated to the production, adding new (radical innovation) or improved (progressive innovation) products or services, and adopting new or improved production methods (Dismukes, 2005). Therefore, the innovation of corn can be attained if, in a setting of technology users sharing a

¹ Localization Coefficient (LC): Technique of the regional analysis that compares the relative importance of corn in the states, with the relative hierarchy the same cultivation has at National level. To estimate the LC, the Boisier's (1980) mathematical expression was used which states that: a) LC=1, indicates that the relative importance of corn in the entity is similar to that it has at national level; b) LC<1, means that in the state, the relative importance of the cultivation is smaller than that of the country, and c) LC>1, shows that the relative importance of corn in the state is greater than that of the country and therefore, it is inferred that that state is specialized in corn production.

group of concepts, knowledge, tools, abilities and a reservoir of concrete and abstract resources (Kurtev & Aksit, 2007), the used TM is transferred by the most efficient producers.

2. Materials and methods

2.1 Research area

Huaquechula is located in the west-central zone of the State of Puebla, Mexico. Its geographical coordinates are the parallels 18° 40' 06" and 18° 51' 48" north latitude and the meridians 98° 21' 18" and 98° 39' 36" western longitude. It has a border to the North with the municipalities of Atzitzihuacan and Atlixco, to the South with Tlapanalá, to the East with the municipality of Tepeojuma and to the West with Tepemaxalco.

2.2 Investigation techniques

The methodology used in the investigation embraced three phases:

2.2.1 Evaluation ex-post of the TM used in the handling of corn

In this phase the following instruments were used:

The survey. It consisted of a questionnaire by means of which most of the data analyzed in the investigation were gathered and systematized. The questionnaire was applied to each producer of a representative sample with 125 questions of closed type, which was proven before its definitive application made in April of 2009. The gathered information embraced demographic, economic, agronomic indicators, as well as those of agrarian and livestock structure.

Sample Size. To determine the sample size the Equation 1 was used (Cochran, 1977):

$$n = \frac{N Z_{\alpha/2}^2 S_n^2}{N d^2 + Z_{\alpha/2}^2 S_n^2} \quad (1)$$

Where:

n = Sample size.

N = 538 producers.

d = Precision wanted for the estimate of corn yield: 50 Kg.

$Z_{\alpha/2} = 1.96$ = Value of the table of the standard normal distribution considering $\alpha=0.05$ (Confidence level= 95%).

S = 241.25 Kg = yield standard deviation, estimated with preliminary data.

The resulting sample was of 99 farmers. The selection of the sampling units (producers) was carried out randomly one by one and without substitution.

Modern Technology Appropriation Index (MTAI). With the survey data the MTAI was quantified to know the degree with which the corn producers used correctly the technologies recommended by the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP). To estimate the MTAI: a) the recommendations made by the INIFAP for each one of the activities of corn cultivation were contrasted, with those the producer applied; b) a nominal value was assigned to the technological package of 100 units

and it was pondered² based on the impact that each one of the components had on corn productivity: 10 for sowing date, 20 for variety, 15 for population density, 25 and 5 for fertilization dose and fertilizer application date, 6 and 4 for type and dose of herbicide, 6 and 4 for type and dose of insecticide and 5 for disease combat, and c) each one of the values pondered were divided by two: the first quotient corresponded to the use of the recommendation and the second to its appropriate handling. Therefore, the value of the MTAI varied between zero and 100 units. To calculate the MTAI the mathematical expression proposed by Damián et al. (2007) to calculate the Agricultural Technology Appropriation Index (ATAI), was adapted (Equation 2).

$$MTAI = \sum_{i=1}^k [(p_i)(APS_i / ATP_i)] \quad (2)$$

Where:

MTAI: Modern Technology Appropriation Index.

k = 10: Number of components of the technological package recommended by the INIFAP.

p_i: Pondering granted to the ith component of recommendation.

$$\sum_{i=1}^k p_i = 100, i = 1, 2, \dots, k.$$

APS_i: Agricultural productive system for the ith component of recommendation; i = 1, 2, ...k.

ATP_i: Agricultural technological package for the ith component of recommendation; i = 1, 2, ...k.

(APS_i/ATP_i): Proportion of used technology, regarding the recommended technology. According to the equation 2, the value of the MTAI varied from zero, when none of the recommendations of the technological package of the INIFAP was used, to 100 when all the recommendations of the technological package were used appropriately.

Rural Technology Use Degree (RTUD). The Rural Technology Use Degree (RTUD) was calculated, which measures in a scale from 0 to 100 the level in which the producers used technologies generated by the producers themselves. To measure the RTUD the use of the following supplies and agricultural practices was considered: Indigenous seed, association and rotation of crops, application of conservation techniques of ground and water, as well as that of manure used as organic fertilizer, granting to each one of them a value of 20 units. The RTUD was obtained by applying equation 3. The Rural Technology Use Degree (RTUD) was calculated, which measures in a scale from 0 to 100 the level in which the producers used technologies generated by the producers themselves. To measure the RTUD the following supplies and agricultural practices were used: indigenous seed, association and rotation of crops, application of conservation techniques of ground and water, as well as that of manure used as organic fertilizer, granting to each one of them a value of 20 units. The RTUD_i was obtained by applying equation 3.

² The pondering was carried out by Drs. Ricardo Mendoza and Abel Gil Muñoz and M.C. Ernesto Aceves, investigators of the Colegio de Postgraduados *Campus* Puebla. The three of them are specialists with more than three decades of experience in the handling of corn.

$$RTUD = \sum_{i=1}^k v_i \quad (3)$$

Where:

RTUD: Rural Technology Use Degree.

k = 5: Number of rural technologies considered for the study.

V_i : Value assigned to the i th rural technology in function of its use or not for the producer. The value was zero if the producer did not use the technology or 20 if he did.

In accordance with the above-mentioned, a producer that did not use any rural technology obtained zero RTUD, if he used one of the five technologies the RTUD was 20, if he used two of the technologies the RTUD was 40, and so forth. When a producer used the five indicated technologies he obtained a RTUD of 100.

Producer typology. Producers were grouped into three categories according to the value of the MTAI and RTUD: a) low (0-33.33), b) medium (33.34-66.66) and c) high technology appropriation (more than 66.66).

2.2.2 Identification of high yield producers

To identify these producers: a) the lowest and highest yields gotten by the producers in each one of the studied municipalities were identified; b) the difference between these yields was calculated; c) this difference was divided by three; d) this quotient was added successively to the lowest yields to build three ranks of producers: low, medium and high yield (efficient producers).

2.2.3 Identification of the TM used by the efficient producers

In the last phase of the investigation the TM used by the efficient producers was identified.

3. Results and discussion

3.1 Evaluation ex-post of the technological model used in the handling of corn

Evaluation is an essential phase of agricultural planning that it is necessary to carry out assiduously, to feedback the decision making. It should provide trustworthy information for the design of programs and in that way to achieve greater levels of efficiency and operative effectiveness, optimize the social impact of the invested public resources and build viable solution proposals.

3.2 Modern technological model and corn handling

In the development of the "Productivist Paradigm" several entities have participated through the time. Being outstanding the Oficina de Estudios Especiales (OEE) created in 1943, the Instituto de Investigaciones Agrícolas (IIA) founded in 1947, the Instituto Nacional de Investigaciones Agrícolas (INIA) instituted in 1960 through the fusion of the OEE and the IIA, and of the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), that arises in 1985 through the fusion of the INIA and the national institutes of cattle and forest investigations. At the moment it is the agency authorized to assist the

demands of producers and agroindustrial chains in cattle and agricultural investigation (INIFAP, 2003).

To make its task, the INIFAP has used the approach “General Recommendations”. It consists of carrying out field experiments in places of interest regions to create “*production formulas*” which are the mean responses of the crops assisted in the experimental cycles. These results are systematized in technological packages and they are recommended for each one of the municipalities that integrate the 190 Districts of Rural Development of the country, with the purpose of promoting the adoption of this TM and the modernization of the Mexican field. The TM recommended for the corn producers of the municipality, is shown in Table 2.

Innovation	Huaquechula
Sowing date	Between March-May
Seed type	H-30, H-33, H-34, H-40, H-48, H-50 H-137, H-139, VS-22
Plant density (ha)	50 thousand plants
Fertilization formula (ha)	140-60-00 and 110-50-00
Fertilization date	It is applied during sowing and second labor
Herbicide type and dose (ha)	Gesaprím 50 (1 kg), 500 FW (1.5 L); Gesaprím 50 (1 kg) plus Hierbamina (1L).
Insecticide type and dose (ha)	Volatón 2.5% or Furadán 5% or Volatón 5% (25-12 kg); Folimat 1000 (0.5 L); Methylic Parathion (1 L) 50% or Malathion (1 L) dissolved in 200 L water by hectare.

Source: INIFAP. 2009.

Table 2. Innovations recommended by the INIFAP for corn handling in the municipality of Huaquechula Puebla, Mexico.

When calculating the MTAI, low (55%) and medium appropriation (45%) producers were found since, on the average, only 32.8 units of the innovations of the INIFAP were used. In addition, it was found that there is no significant relationship between the use of these technologies and yield ($n=99$, $r = 0.0155$, $p=0.8789$) and that there is no significant statistic difference among the yield means of the low and medium appropriation corn producers ($t=-0.6930$, $p=0.4900$), even when the latter used 15.5 more units of the recommended modern innovations (Table 3).

Indicators	Low		Medium		Municipal Average	
	Number	%	Number	%	Number	%
Producers	54	55	45	45	99	100
Yield	2196		2251		2221	
MTAI	25.8		41.3		32.8	

Source: own elaboration with data obtained from the survey, 2009.

Table 3. Number of producers, yield (Kg ha⁻¹) and MTAI, by type of producers of Huaquechula Puebla, Mexico.

It is probable that the reduced use of the TM recommended by INIFAP was due to the fact that the method “General Recommendations” is based on the following suppositions:

- i. In the defined regions (DDR and municipalities), corn producers have a reasonably similar handling, eluding the diversity of agroecosystems and producers existing in these geographical spaces.
- ii. Only the edaphic-climatic factors influence corn handling. It does not take into account that the producer’s access to the production means influences manifestly this handling.
- iii. Greater yields can only be obtained if modern inputs are used. However, the high costs modern inputs put them out of reach of the small producers’ budget, with yearly mean remunerations of 3,700 pesos (Escalante, 2006).
- iv. Producers are unable to generate technologies for corn handling. Owing to the shortcomings of most of these suppositions, this TM could not be adapted to the average conditions in which the municipality producers live and produce.

3.3 Rural technological model and corn handling

This TM, has been created by a wide social base on a local scale that includes millions of peasants. Their roots are empiric knowledge and innovations the communities have used in diverse disciplines of the knowledge and resource administration ((Topfer, 2000). This TM has been favored by scientific and civil organizations and it is the base of the “Paradigm Agro-ecologic” (Altieri & Toledo, 2011). When these innovations reign in corn handling, it is considered a traditional and inefficient agriculture; for this reason, there are no experimental fields to promote its improvement and, for the same reason, they are not organized in technological packages. It is a predominant the idea that the only knowledge is the scientific one; another kind of knowledge does not have the validity nor the rigor that western science demands to generate technologies (De Sousa, 2006). This notion has no scientific support. Empirical data in Table 4 show that in the TM used in corn handling, modern and rural technologies interact with an evident supremacy of the latter. When calculating the RTUD it was found that it is 45 units higher than the MTAI on the average and that a very weak relationship is presented ($n=99$, $r = 0.2554$, $p=0.0107$) between RTUD and yields. A statistical difference was found between the yield means of the corn producers of medium and high RTUD ($t=3.6361$, $p=0.0.0004$) (Table 4).

Indicators	Medium		High		Municipal Average	
	No.	%	No.	%	No.	%
Producers	29	29	71	71	99	100
Yield *	2010 a		2308 b		2221	
RTUD	55.9		86.9		77.8	

Source: own elaboration with data obtained from the survey, 2009.

* Different letters in the yield means indicate that there is significant statistical difference among them (Tukey Test, $p < 0.05$).

Table 4. Number of producers, yield (Kg ha⁻¹) and RTUD by type of producers of Huaquechula Puebla, Mexico.

The TM used by the municipality producers, confirms the importance of rural technologies (Table 5).

Innovation	Huaquechula
Soil Conservation (%)	Rustic dams (46), living terraces (4), stone terraces (3) ditches (9), Soil conservation techniques were not applied(37)
Sowing date(%)	Jun (68) and July (32)
Seed variety (%)	Indigenous (96) and hybrid (4)
Plant density (ha)	65,584
Crop Association (%)	Corn associated with: pumpkin (58), bean (6) and pumpkin and bean (4). Crops were not associated (32)
Crop Rotation (%)	Alternation with: peanut (25), pumpkin (2), bean (5) and sorghum (43). Crops were not alternated (25)
Average manure application (t/ha)	875 applied before sowing
Fertilization formula (%)	29 formulas applied: 138-00-00 (10), 69-00-00 (9), 30.75-00-00 (9), 115-00-00 (8), 51.25-00-00 (7), 41-00-00 (6), 92-00-00 (6) and 61.5-00-00 (5) and other formulas (30). Not applied (10)
Fertilization date (%)	During sowing (12), first labor (55), second labor (23)
Name and dose of herbicide /ha (%)	6 types of herbicides applied, prevailing: Esterón 1 lt/ha (36), faena 1 lt/ha (14), basagrán 1 lt/ha (11); and other herbicides (9). Not applied(30)
Name and dose of insecticide /ha (%)	8 types of insecticides applied, prevailing: Furadán 1 l/ha (26), Methylic Parathion 1 lt/ha (7), Othesrs (11). Not applied (56)

Source: own elaboration with obtained data from the survey, 2009.

Table 5. Innovations used in corn handling by the average producer of Huaquechula Puebla, Mexico.

A more detailed analysis of this TM and the one recommended by the INIFAP show certain coincidences only in the dates of fertilizer application. In the other tasks carried out, there are unquestionable discrepancies, but standing out were the following ones:

- i. The sowing dates recommended (March-May) were suitable for the plateau of Puebla, but not for the warm-dry areas as Huaquechula, with a rainy season that usually begins at the end of June or beginning of July.
- ii. The INIFAP recommended the sowing of hybrids and almost all the producers used indigenous seeds because: a) they are easy to get; b) the families prefer them for the elaboration of tortillas; c) they possess a millennial adaptation to the local agroecosystems affected by recurrent droughts; d) their production costs per hectare are notoriously inferior to that of the hybrids; e) they have a stable productivity through the time, and f) they are pillars of the cattle reproduction, on providing of greater quantity and quality of forage. The municipality peasants have, on the average, 1.9, 0.7, 0.7 and 0.3 heads of bovine, equine, mule and asinine livestock respectively. Some of these races are used as draft animals since 52% of the producers use them to furrow, 54% to give the first labor and 65% the second labor.
- iii. The density of plants per hectare used by the producers was greater than the recommended one. Probably this is due to that they fertilized their soils with a mixture

of manure and synthetic fertilizers, where the former promotes a bigger absorption of nutrients, improving the fertility of the soils.

It stands out that most of fertilizers used by the producers were nitrogenous, as long as the INIFAP also recommends those containing phosphates. This may be due to the fact that the soils in which the experiments were carried out to generate the best economic doses of fertilization possessed certain edaphic properties that do not coincide with that of the soils in which the peasants sow, to which, on the average, almost a ton of manure per hectare a year was applied.

- iv. 70% of the corn producers used herbicide as manpower substitute in corn handling. The exclusion of the subsistence producers out of the neoliberal model of accumulation has originated an intense emigration and manpower aging. Of the total of the population of the corn producers' family (499 people) 38.5% had emigrated and the producer average age was of 57.3 years.
- v. The least used agrochemical were the insecticides, due to the use of rural technologies such as the association and rotation of crops.
- vi. Roughly, there was a reduced use of agrochemicals because their high costs put them out of reach of the corn producers' budget, with an annual average expense per capita of 9,194 pesos.
- vii. There are three activities (soil conservation, association and rotation of crops) and two inputs (indigenous seed and manure) that INIFAP does not consider in its TM, even though the municipality corn producers have used them daily for years. In brief, it can be stated that it is a question of agro-ecosystems that, to prosper, like in any other, multiple tasks (soil preparation, sowing, tillage, fertilization, etc.) had to be, carried out successively at field level.

To this end, corn producers used modern (machinery, hybrids, agrochemicals) and traditional (draft animals, indigenous seeds, association and rotation of crops, soil conservation, manure) technologies, with an evident prevalence of the latter. This technological syncretism is one of the elements that defines and characterizes the rural handling of corn.

The persistence of this handling method could be due to the interaction of several factors:

- i. The innovations were derived from rural knowledge systems, where producers had adopted, adapted and transmitted to other generations by oral and experiential means, a TM that turned out to be the most appropriate for its agro-ecosystem and life conditions.
- ii. They possessed higher productive efficiency for the following reasons:
 - a. Conservation of soil and water prevented loss of nutrients and water that are indispensable to improve the productive capacities of soils.
 - b. The association of crops is the sowing of two or more crops in the same plot. this helps to articulate different elements of the agro-ecosystem (crops, soils, plants, animals); create synergies that increase the productivity of resources whose cost tends to zero (solar energy, air, nitrogen, carbon); group plants (corn-legumes) with diverse energy efficiency, growth habits and root systems, use in a more effective way the solar energy, nutrients and water. For instance, the corn-bean/Lima bean association powers the soil-plant-environment relationship, since legumes fix atmospheric nitrogen that is used by corn, and promotes the biodiversity of flora

- and fauna that, in turn, creates trophic chains and woofs that regulate plague growth and the low use of insecticides.
- c. Crop rotation reduces problems of weeds, plagues and diseases; it increases the levels of available nitrogen in soil, reduces the necessity of synthetic fertilizers and, along with soil-conservative farm practices, diminishes soil erosion (Ball et al., 2005).
 - d. The use of manure is a key indicator of soil quality since it provides nutrients, improves the structure and texture of soil, as well as physical, chemical and biological fertility of soil, increases airing, penetration and retention of water, stimulates the development of beneficial microorganisms for the plant and is essential for carbon capture (Fenton et al., 2011).
- iii. They have an economic and nutritional complementariness. The poly-crops protect the rural families from total economic damages caused by climatic factors (drought, frost and hailstorms) which can affect some of the cultivated species, but hardly all. Likewise, corn-bean/Lima bean are essential for rural diet, since the corn provides carbohydrates and other elements (such as niacin) and the bean/Lima bean contributes proteins, tryptophan and lysine (Long-Solis & Vargas (2005).
- iv. It encourages the cropping-cattle raising interaction that, for these corn producers, is a strategy of essential survival that has allowed them to diversify their sources of revenues and feeding, have organic fertilizer, have animal traction force and recycle the organic waste the rural family generates.
- v. They are more resilient; that is to say, the corn agro-ecosystems managed with the rural TM has a greater capacity to recuperate their productivity even though they are usually exposed to climatic interferences.
- vi. Finally, its persistence is due to the fact that it consists of sustainable agricultural systems inspired by biology (Vincent et al., 2006). That is to say, it is biomimetic because its handling is based on an ecological engineering that assembles, in the time-space different components of the agro-ecosystem: crops, soils, trees, animals and environment (Altieri, 1991). Likewise, these systems integrate geologic, physical, chemical and biological processes through flows and cycles of matter and energy that settle down between live organisms and their environmental contribution (Connor et al., 2011).

3.4 Technological model of the efficient producers

In order to study this TM, the efficient corn producers were firstly identified and, later, the technologies they used in corn handling were determined.

3.5 Identification of the efficient producers

When applying the methodology proposed to identify the efficient corn producers the following results were obtained: a) the lowest and highest yields were 1,400 and 3,100 Kg ha⁻¹ respectively; b) the difference was 1,700; c) the quotient value was 567, and d) the ranks calculated for low-, medium- and high-yield producers were of 1,400-1,967, 1,968-2,534 and >2,534 Kg ha⁻¹, respectively. The features of these types of producers are shown in Table 6.

Indicators	Low		Medium		High		Municipal Average	
	No.	%	No.	%	No.	%	No.	%
Producers	24	24%	53	54%	22	22%	99	100%
Yield	1740 a		2206 b		2783 c		2221	
MTAI	32 a		32.9 a		33.6 a		32.8	
RTUD	68.3 a		80.8 b		80.9 b		77.8	

Source: Own elaboration with data from the survey, 2009.

* Inside each file (Yield, MTAI and RTUD), different letters in the means indicate that there is significant statistical difference among them (Tukey Test, $p < 0.05$).

Table 6. Characteristic of the corn producer types of Huaquechula Puebla Mexico, according to their yields (Kg ha^{-1}), MTAI and RTUD.

In these data it is observed that:

- i. The medium productivity corn producers prevailed.
- ii. Almost one of every four corn producers was efficient.
- iii. In corn handling, modern and rural practices interact, with the latter prevailing since the RTUD among the high yield producers was greater (47.3 units on the average) than the MTAI.
- iv. It was found a significant difference among corn yields of the producers, being bigger among the efficient producers with regard to those of low and medium yield (Tukey test $p < 0.05$).
- v. The increment of the MTAI was not reflected consistently in a significant increment of the unitary yields ($n=77$, $r = -0.0908$, $p=0.4324$); while the higher the RTUD, the yields were consistently higher ($n=77$, $r = 0.4621$, $p < 0.0001$).

3.6 Identification of the technological model of the efficient producers

The identification of the efficient corn producers is an essential step to know the TM they used in corn handling (Table 7).

When contrasting these innovations with those the municipality peasants used (Table 5), it stands out that:

1. Most of the producers have used a TM reasonably similar in corn handling, based on a syncretism of modern and rural technologies.
2. The efficient producers used, in higher degree, rural technologies in corn handling except in soil conservation, because most of them possess lands with smaller slope (Table 8).
3. When using less modern technologies, discounting the insecticide, the corn handling had lower costs per hectare.

Innovation	Huaquechula
Soil Conservation (%)	Rustic dams (36), stone terraces (9) and ditches (9), Soil conservation techniques were not applied (46)
Sowing date (%)	Jun (73) and July (27).
Seed variety (%)	Indigenous (100)
Plant density (ha)	66,242
Crop Association (%)	Corn associated with: pumpkin (64) and bean (4). Crops were not associated (32)
Crop Rotation (%)	Alternation with: peanut (32), and sorghum (54). Crops were not alternated (14)
Average manure application (t/ha)	989 applied before sowing
Fertilization formula (%)	14 formulas applied, prevailing: 69-00-00 (23), 41-00-00 (14), 30.75-00-00 (9), 51.25-00-00 (9); other formulas (45). Not applied (0)
Fertilization date (%)	During sowing (9), first labor (64), second labor (27)
Name and dose of herbicide /ha (%)	Faena 1 lt (32), and Esterón 1 lt (27), Not applied (41)
Name and dose of insecticide /ha (%)	4 types of insecticides applied, prevailing: Furadán 1 l/ha (32), Others (23). Not applied (45)

Source: Own elaboration with data from the survey, 2009.

Table 7. Technological Model used by the efficient producers in corn handling in Huaquechula Puebla, Mexico.

3.7 Socioeconomic and technological characteristics of corn producers

In Table 8 some socioeconomic and technical features of the municipality producers are shown according to their yields.

Indicators	Low		Medium		High		Municipal Average	
	No.	%*	No.	%*	No.	%*	No.	%*
Age	57.7		57.6		56.2		57.3	
Family size without migrants (Prom.)	2.8		3.2		3.2		3.1	
Migrants/family (Prom.)	1.7		1.9		2.2		1.1	
Remittances (\$/month per capita)	173		171		188		175	
Expense (\$/month <i>per capita</i>)	737		759		816		766	
Corn sowed area prom.(ha)	1.68		1.92		2.1		1.89	
Without slope (No.)	6	25	16	30	10	45	32	32
With little slope (No.)	13	54	35	66	11	50	59	60
With a lot of slope (No.)	5	21	2	4	1	5	8	8
Primary multi-active ** (No.)	14	58	43	81	17	77	74	75
Secondary multi-active *** (No.)	8	34	8	15	4	18	20	20
Peasants **** (No.)	2	8	2	4	1	5	5	5
Possession of tractor	1	4	10	19	4	18	15	15
Yoke of oxen Possession	13	54	17	32	10	45	40	40
With technical consultantship	1	4	6	11	2	9	9	9
Bulls, cows, mules & horses (Heads No.)	2.5		3.6		4.4		3.5	
Sheep & goats (Heads No.)	9.3		14.9		18		14.2	
(Fertilizer application (Kg/ha)	608		948		989		875	
Plants' density /ha	63,570		66,223		66,241		65,584	

* The % is in relation to the total of producers according to their unitary yields.

**It includes producers that cultivated corn and carried out other tasks of economic branches of the primary sector.

*** They executed other activities in the secondary and tertiary sectors, besides those dedicated to corn cultivation.

**** It includes the producers that sow only corn.

Table 8. Socioeconomic and technical characteristics by type of producers according to their yields per hectare of Huaquechula Puebla, Mexico.

In this table, the following could be observed:

- i. The three types of producers had living conditions that were essentially similar. The similarities were noticeable mainly between medium and high yields producers, having greater access to production means than those low yield producers.
- ii. The efficient producers had slightly greater quantity of manpower at their disposal, because the rural innovations are intensive in this factor of the production.

- iii. 21 efficient producers were multi-active, but 77% of them carried out other tasks in the primary sector and 18% in other sectors. The percentages for corn producers of medium and low yields are 81 and 15 and 58 and 34, shown in the same order. The multi-activity carried out in the same region in the secondary and/or tertiary branches, has transfigured agriculture in a strategy of secondary life, causing that the producer reduce his specialization in crop handling. The multi-activity carried out outside the community, because of the emigration, has caused a total technical rupture of the corn handling. The lingering interruption of corn sowing by members of the family is an obstacle for the transmission of the traditional knowledge (Nadal & Wise, 2004).
- iv. An element with greater deterioration among the low yield corn producers is the agriculture-cattle raising synergy, causing the quantity of applied manure to be smaller, thereby diminishing the fertility of the agricultural soils and their productive capacity to sustain greater densities of plants and unitary yields. The probable interaction: greater use of rural technologies and the smaller multi-activity of the efficient corn producers in economic branches disjointed of the agricultural and cattle activities, explains their greater productivity.

But the efficiency of the rural TM does not confine itself to the yields per hectare because it has been demonstrated (Etchevers et al., 2001) that these agricultural systems act as sinks of CO₂, main GEG that is causing the global warming. This way, subsistence corn producers have contributed with environmental services that benefit the whole humanity.

On the other hand, the modern TM has caused deforestation, structural loss and salinization of soil, loss of nutrients and contamination with fertilizers and pesticides (Pengue, 2005). This TM has contributed 14% of the planet warming (Stern, 2007). The modern TM on undermining the natural conditions, in which the agricultural activity is carried out, endangers its persistence in the time because it is more vulnerable to the alterations of temperatures and precipitations originated by the climatic change. This vulnerability was evidenced at the beginning of 2011 with farmers of Sinaloa (Mexico) that were affected by a strong freeze, to the extent that 90% of the 715,000 hectares sowed during the cycle autumn-winter 2010-2011, registered high indexes of damages (The Economist, 2011).

3.8 The proposal of sustainable rural development (SRD)

For the promoters of field modernization, the "technification" of agriculture would originate an increase in production that, in turn, would create greater agricultural surpluses and revenues, facilitating the producers to acquire a greater quantity of goods and contributing to the expansion of the aggregate demand. This way, it would be possible to attain high consumption and development, identified with the lifestyle instituted by the countries of Western Europe and, mainly, with the frantic consumerism encouraged by the United States of America. This schematic vision of development contrasts with the notion of the SRD, grounded in the conceptual contribution the World Commission on the Environment and the Development in its report "Our Common Future" (1987), where sustainable development is understood as that that satisfies the necessities of a generation without compromising the capacity of the future generations to satisfy their own necessities. In this framework, the SRD comprises a double process re-created cyclically and simultaneously. The first moment, includes the production of goods that are required for the satisfaction of necessities. The second moment embraces the satisfaction of human necessities (biological

and cultural), in concrete terms as the rural society perceives and solves them. To this end, man settles complex and dynamic relationships with nature that should safeguard the natural conditions that support this production. That is to say, to be sustainable through the time. The proposal of transfer of the TM of the efficient corn producers is located in the framework of the SRD for the following reasons:

- i. This TM provides corn and other goods obtained from the productive complex “cornfield”, which are the base of rural gastronomy where corn and most of the plants associated to it, are used and/or consumed by rural families or by their livestock. In the same way, the production-consumption of corn has been the base for the re-creation of the rural worldview, understood as the form in which a social group interprets the world, defines its daily behavior and its bond with a social group. Furthermore, the production of this grain has been the origin of rural organization forms that have lasted until our days, such as the “mano vuelta”.
- ii. With the transfer of the TM of the efficient corn producers it is possible to increase, in the case of Huaquechula, the yields of the low and medium yield producers by 37% and 21% respectively. We suppose that this increase can be more substantial if the rescue and revaluation of the rural TM becomes a priority of the Mexican State.
- iii. The deterioration of the agriculture-cattle raising synergy and the loss of manure, are an enormous opportunity to promote the use of the organic waste generated by the inhabitants as organic fertilizer. According to the Secretaría de Desarrollo Social [SEDESOL] (2010), in 2009 the inhabitants of the country generated 20 million tons of organic residues. As it is known, about 20% of the original weight of the organic garbage becomes compost after a process lasting about three to four months. Therefore, at least, 12 million tons of organic fertilizer can be produced in a year if they are distributed in a proportional way among the 6.5 million rain-fed hectares sowed with corn (SIAP, 2010). Diverse studies have demonstrated that the use of compost as fertilizer increases the availability of nutrients and soil productivity, without contaminating the environment (Ouédraogo & Zombré, 2001; Lima et al., 2004). Likewise, compost production can represent an important productive chain for the generation of thousands of jobs in the field and the city.
- iv. The handling of this TM requires greater consumption of human energy. Therefore, to foment its use it would be necessary to grant the subsistence producers substantial subsidy per cultivated hectare. It is a question of applying the Principle of Difference (or of equity), where the primary social goods (rights, freedoms, opportunities, revenue and wealth) are distributed in an unequal way to favour the individuals that are in worse situation (Rawls, 1975).
- v. The use of the rural TM has performed such environmental services as: the mitigation of GEG emissions and of the impacts of disasters associated with natural phenomena, biodiversity conservation and protection of hydric resources (De Schutter, 2010). The economic retribution to the peasants for these environmental services should be considered as an essential mechanism of the environmental national policy.

The transfer of the TM of the efficient corn producers is viable for the following reasons:

- i. The institutional framework “Sustainable Modernization of Traditional Agriculture” (MasAgro) exists with the purpose of rescuing and improving the handling,

productivity and sustainability of the basic grain producers (Diario Oficial de la Federación [DOF], 2010).

- ii. The producers know and have managed this TM, which coincides with their natural environment and the circumstances in which most of them produce and live.
- iii. The governments of the federative entities have radio and television stations, massive media that have been used already with success to transfer technologies, mainly the former. Radio is a medium that allows its transmissions are received quickly, thanks to its penetration in geographical regions of difficult access by means of waves with frequency and amplitude modulation at low cost. It also has the advantage of ubiquity since it allows the receiver to make other tasks, at the same time that he or she listens to the radio. Furthermore, these governments have the human resources and infrastructure to execute all the phases that the model of technological transfer comprises.

The proposal of transferring the TM used by the efficient producers is an idea that has a technological origin, but that it surpasses this question since it intends as a mean to achieve SRD: to enlarge the productivity of corn and the plants associated to it, to improve the revenues and the nutrition of the rural producers of basic grains, to diminish the poverty indexes, to make the producers become the protagonists of the diffusion of the rural TM, and to provide more environmental services to the society (De Schutter, 2010). It is also planned to create jobs, reinforce cultural identity, as well as solidarity and social organization among the corn producers. It is thought that the SRD can be reached more quickly, if it is passed through the PT of the efficient producers to the "Agro-ecologic Paradigm."

4. Conclusions

In the Mexican field, extreme poverty, climatic change and low productivity that have become obstacles to reach the SRD coexist. In order to reverse this process a methodology consisting of three steps is proposed: to evaluate the efficiency of the modern and rural innovations used in corn handling, to identify the efficient producers and the TM they use to promote its transfer to the other producers. The results of this investigation indicate that this process is feasible since this TM it is adapted, roughly, to the conditions in which the peasants produce and live. With the transfer of the innovations used by the high yield producers, it is probable to increase the yields per hectare of corn and the plants associated to this crop, to diminish extreme poverty, provide more environmental services to the society, create jobs, reinforce the cultural identity, the social solidarity and the political empowerment of the producers, without undermining agriculture sustainability. But mainly, the transfer of this TM can be the shortest and effective way to pass from the rural handling to the agro-ecologic handling of corn.

5. Acknowledgments

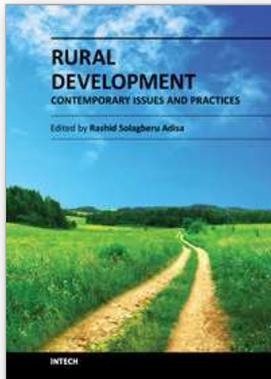
To FOMIX-CONACYT and the Government of the State of Puebla for the financing granted to make this investigation. This publication was made during the postdoctoral stay carried out in the Mastership in Sciences in Rural-regional Development of the Universidad Autónoma Chapingo.

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Rural Development - Contemporary Issues and Practices

Edited by Dr. Rashid Solagberu Adisa

ISBN 978-953-51-0461-2

Hard cover, 408 pages

Publisher InTech

Published online 20, April, 2012

Published in print edition April, 2012

Development of rural areas has witnessed increasing attention globally, especially over the past three to four decades. The highpoint in the renewed global interest in the development of rural people and their environment was reached with the setting of the Millennium Development Goals (MDGs) in the year 2000. All of the set goals are basically rural development goals. With less than four years to the deadline for the achievement of the MDGs, it is almost certain that the goals are far from being achieved in, especially, most developing countries for whom the MDGs were essentially set. The struggle thus continues for rural development. As long as problems of poverty, disease, illiteracy, unemployment, poor infrastructure, environmental degradation and others persist (or increase) in rural communities, better and more result-oriented solutions to perennial and emerging problems of rural communities would be required. But rural development, in spite of the variations in thresholds of rurality among nations, is not exclusively a Third World or “developing countries” process, owing to its multi-dimensionality. It is a global phenomenon that obviously requires global strategies. This book not only looks at rural development from its multi-dimensional perspectives, it is also a product of the experiences and expertise of distinguished scholars across the continents. Aiming to provide a comprehensive single volume that addresses salient issues and practices in rural development, the book covers themes ranging from sustainable agriculture, biodiversity conservation, strategic environmental assessment, renewable energy, rural financial resources, assessment of protected areas to statistics for rural development policy. Other subject matters covered by the book include social marginality, land use conflict, gender, cooperatives, animal health, rural marketing, information and communication technology, micro-business, and rural economic crisis. The book is thus an invaluable source of useful information on contemporary issues in rural development for researchers, policy makers, and students of rural development and other related fields.

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