

## **A sustainable nexus in Mayan communities**

Aime Medina, IRRI Mexico Communications Coordinator  
Monserrat González, IRRI Mexico Director  
aime@irrimexico.org  
(52) 55 50 55 56 86  
Puebla 124, Colonia Roma, Delegación Cuauhtémoc, C.P. 06700

### **Introduction**

As the population continues to grow, the demand for food production is causing tremendous pressure on hydric and energy resources, by 2050 sixty percent more food will need to be produced in order to feed the world population. That is why the actions taken to understand and improve the water, energy, and agriculture nexus are key for achieving sustainable development goals.

But how are these three elements related? According to FAO data, 70% of the world's freshwater is used by agriculture, also food production chain uses 30% of the total energy produced worldwide and if 60% more food will need to be produced, the quantity of water and energy destined to agriculture will also need to increase. To achieve this goal other elements need to be taken into account, for example, the soil quality and availability.

Mainstream unsustainable agricultural practices have resulted in moderate to high degraded soils due to erosion, salinization, compaction and chemical pollution of 33 percent of them (FAO, 2011). The expansion of the agricultural areas is not an option, during the last decade 13 million of forests were converted, mainly for agricultural purposes, damaging other environmental services provided by these ecosystems.

These elements that affect the food production systems are directly related to poverty and gender inequality. Women are the most affected by climate change and they have a key role in transforming the nexus into a sustainable model. They are responsible of cooking and they invest their time in collecting firewood, water and harvest to transform them into nutritious food for their families, if they have to invest more time in water recollection due to over exploitation and pollution of the natural sources of water, then women will reduce the time they invest in nutritious, diversified and varied meals for their families, especially for children, deriving in malnutrition and emaciation that directly affect the cognitive development of children, the quality time children are able to spend in schools, the time adults are present in their jobs, and at the same time this increases the burden of medical expenses.

Through this paper, I will analyze the specific study case of the nexus applied in the Yucatan Peninsula, Mexico. The International Renewable Resource Institute (IRRI Mexico) is a Mexican organization working to change in a positive way the relationship between the

different elements of the nexus in the region, working with rural and indigenous communities to protect natural resources and environmental services to transform them into sustainable and clean food, fuel, and water access, associated to economic and social services like economic diversification and health promotion.

### **A community with Mayan roots**

The Yucatán Peninsula is located in the south of Mexico, this region is characterized by a karstic soil mainly formed by limestone, a highly porous rock, which causes that rainwater filters directly into the ground water sources. This natural phenomenon forms wide natural wells with circular contours, called cenotes.

This area has been habited by the Mayan civilization, the oldest remains of the presence of the Mayas date back to 9,000 years. Between the years 2500-2000 b.C. and 300 a.C., they were one of the most important cultures of America; they developed unique building techniques, manufacture and decorations of utensils for rituals and sanctuaries, and their calendars and advances in astronomy last until our days (Quezada 2010, 21). Mayan culture and traditions are still an important part of the Yucatan inhabitants, 30% of the actual population speak Maya.

Yucatan is a region that depends directly on agriculture, they are the number one national producer of citrus and the 4th national pig meat producer. A total of 108,903 people work in the agricultural sector, as a result, this is the 4th productive activity that generates more employment in the region.

Nevertheless, the diversification of productive activities has focused on the diversification of subsistence farming, beekeeping, subsistence livestock production, and "others began to establish their own businesses for the provision of goods and services, and there were those who were contracted as employees in Mérida (the capital city) "(Berdegúe and Modrego Benito 2012, 76). However, the jobs that they have access to in the nearby urban centers are badly payed and keep people in the poverty line. At the same time, there is now greater schooling of young people, but under an educational model that discriminates agricultural activities and the rural and indigenous lifestyle.

These phenomena help us understand the precarious conditions of agricultural and livestock activities in this territory; lack of incentives, financing and investment opportunities, lack of interest of the new generations in engaging in such activities, lack of access to technology and innovation in the field, high rates of internal migration and the lack of research and dissemination of sustainable and organic alternatives in food production processes.

In addition, the main challenges that farmers are facing are the high prices of external agricultural inputs, transportation costs, the low price of their products in the market, the high rates of intermediaries, the lack of access to key resources such as water and energy, and the effects of climate fluctuations in their production.

Current inputs and training support, mainly provided by government agencies for small farmers, do not have a sustainable framework and keep providing products and services based on intensive agriculture, the use of agrochemicals and industrialized livestock practices, without considering any organic, environmental friendly, and local alternatives that recognize and meet the environmental, social and economic needs of the communities.

The current education system does not adjust to the reality of the region, making young people lose interest in agricultural and livestock activities, now youths migrate to bigger cities nearby to have access to a better salary, but they are trapped in low remunerated jobs, such as domestic work, waitresses and other low-skilled jobs that only reproduce poverty cycles, which sometimes forces them to migrate to the United States looking for more and better opportunities.

Despite institutional efforts to reduce gender discrimination, there is currently a system that reproduces differences by gender and therefore inequalities. Currently, the role of women is still associated as a reference to non-remunerated nor recognized housework; "Women still have limitations to develop their own businesses, to participate in public decisions and a considerable proportion works in domestic service receiving a paltry salary" (Berdegué and Modrego Benito 2012, 103).

## How is the nexus working?

### Water

Hydric resources in Yucatan represent 25% of the water available in Mexico, also this is one of the few states of the country in which water scarcity is not a serious problem. The average water availability per capita in the Yucatan Peninsula is of 6,212 m<sup>3</sup>/hab/year (SEMARNAT 2016); which means that each inhabitant of the region has an average of 17,019 liters per day for their daily activities, a lot more than the minimum 25 liters per person established by the World Health Organization.

■ Agriculture ■ Urban supply ■ Services sector ■ Industrial uses

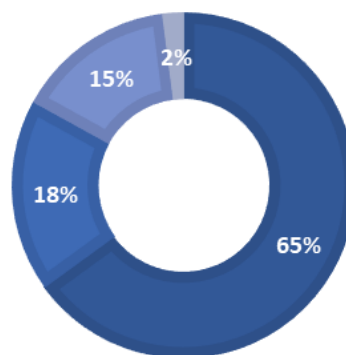


Figure 1. The use of water in Yucatan, CONAGU

Shallow wells provide 53% of the water supplies in the region, the other 47% is supplied by the cenotes or deeper wells at 40 or 100 meters deep. According to CONAGUA database, agriculture uses 65% of the Yucatan Peninsula water resources, 18% is used for urban supply, industry uses 2% and the services sector uses 15% of the resource.

Due to the soil porosity, the aquifer recharge is not a problem but at the same time this compromises the water quality. Yucatan, is one of the States in Mexico with the lowest sanitation infrastructure, only 5% of the population have adequate coverage of this service, most of the wastewater is being disposed directly to the subsoil through sinks, only in some of the main cities of the region are used septic tanks, latrines and in only some of the new constructions of Merida have sanitary sewer networks connected to deep wells through which the waste is injected into the saltwater aquifers that underlies the fresh water deposits.

Relationship between biodigester and water bodies in Yucatán

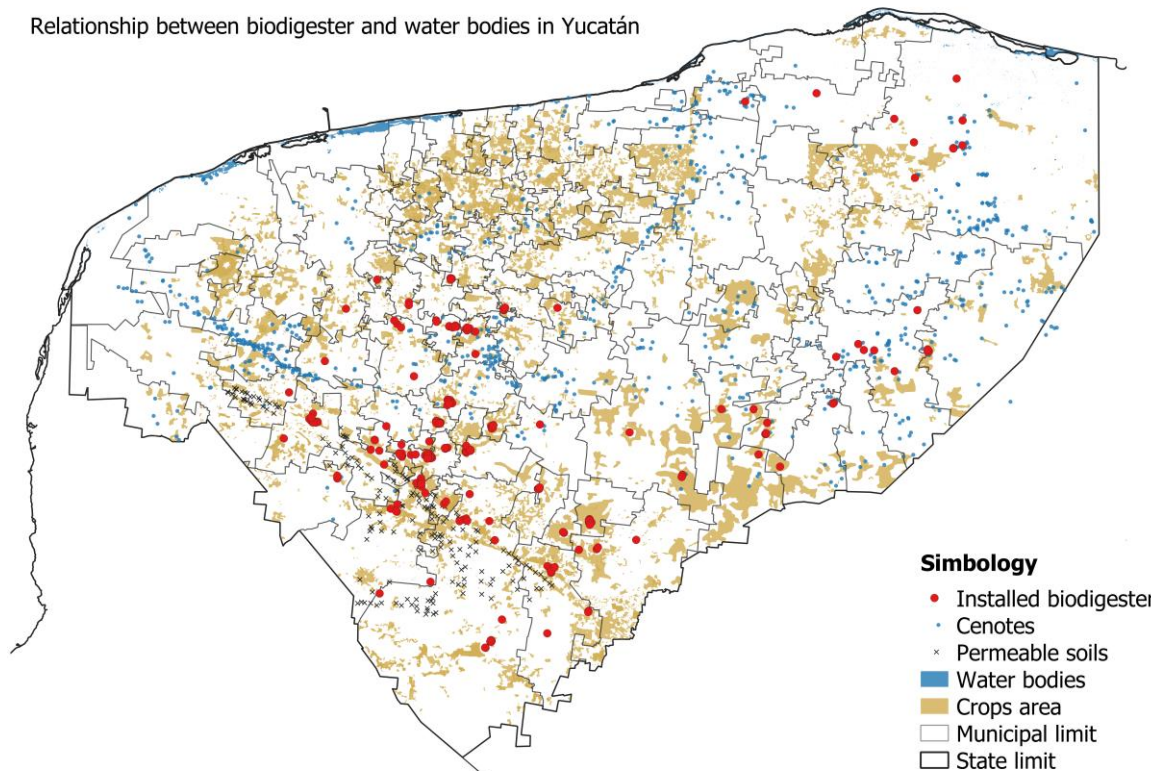


Figure 2. Relationship between biodigesters, water bodies and agriculture in Yucatan, Original work of the International Renewable Resource Institute, 2019.

## Energy

The Yucatan Peninsula is the second place in Mexico with the highest energy prices due to the lack of adequate infrastructure in the region which is obsolete and insufficient for a growing population, especially in rural areas where they depend on electrical pumps for water supply and during drought time the old infrastructure fails making families face water scarcity to irrigate their crops and, sometimes, even to cover their domestic needs.

The energy sector in Yucatan is the number one Greenhouse Gases producer and in rural areas, firewood is the main source of energy and is also considered a traditional way of food preparation for 61% of the population in the area. According to the National Council of Evaluation of the Social Development Policy 2014, 40% of the population of Yucatan uses firewood to satisfy basic needs such as cooking.

The pollutants generated by burning firewood cause pulmonary diseases, which are the second death cause in the State, affecting mainly women and children. To obtain this source of energy 57% of the population spends more than two hours per week in collecting the wood, and 85% of them obtain it from the jungle, deforesting the nearby areas of the communities.

### **Food production systems**

Food production is one of the most important activities in Yucatan, agriculture and tourism are the economic pillars of the region. Yucatan is the first national producer of citrus and the fourth national producer of pork meat. 18% of the state territory is used for agricultural activities and 2% for meat production.

During the 2010 census, forage was the principal crop with 558,989 ha harvested areas (72%); the second was corn with 168 647 ha (21%); the third was henequen with 25,306 ha (3%) and citrus with 19,622 ha (3%); and the last one vegetables and other fruits with 6,763 ha (1%). Unfortunately, to produce this amount of food 57% of the farmers use synthetic fertilizers and pesticides that filter into the water sources of the region polluting water.

Rainwater is the main source of water that farmers use to produce food, most of the farmers sow in spring, wait for the rain in the summer and harvest at the end of that season, this is also caused by the lack of infrastructure because they do not have enough water in their land to water their crops. But during the drought, 61% of the farmers use water from the municipal supply network.

Agricultural activities are the third biggest GHG pollutant of the State, mainly because of animal manure (SEDUMA 2013, 2), 61% of the farmers just stack the manure producing pollution spots, 15% dispose of them in sumps polluting the water and generating 1844,800 tons of CO<sub>2</sub> annually, and only 23% of them uses manure as a fertilizer, which produces a direct impact on climate change. Unfortunately, 85% of the farmers said they have lost their harvest due to a natural phenomenon, 57% because of drought.

Although there is a large production of food in the region 68.3% of the population of Yucatan suffer from food insecurity, mainly in rural areas where 37% of the population lives in moderate poverty situation. According to national statistics, 48.5% of women suffer obesity, 56.7% of men, 46.5% of boys and 43.8% of girls (National Institute of Public Health 2012, 85).



These problems demand interventions that recognize the current needs of the population, the ecosystem and the need for greater citizen participation in the public decision making. That is why the project of IRRI México is presented from a comprehensive methodology that recognizes the link, interdisciplinarity and complexity of the nexus, taking as a starting point the interrelation of those factors that are recognized as the areas of long-term impact of the project: food and energy security, and reduction of pressure and water pollution.

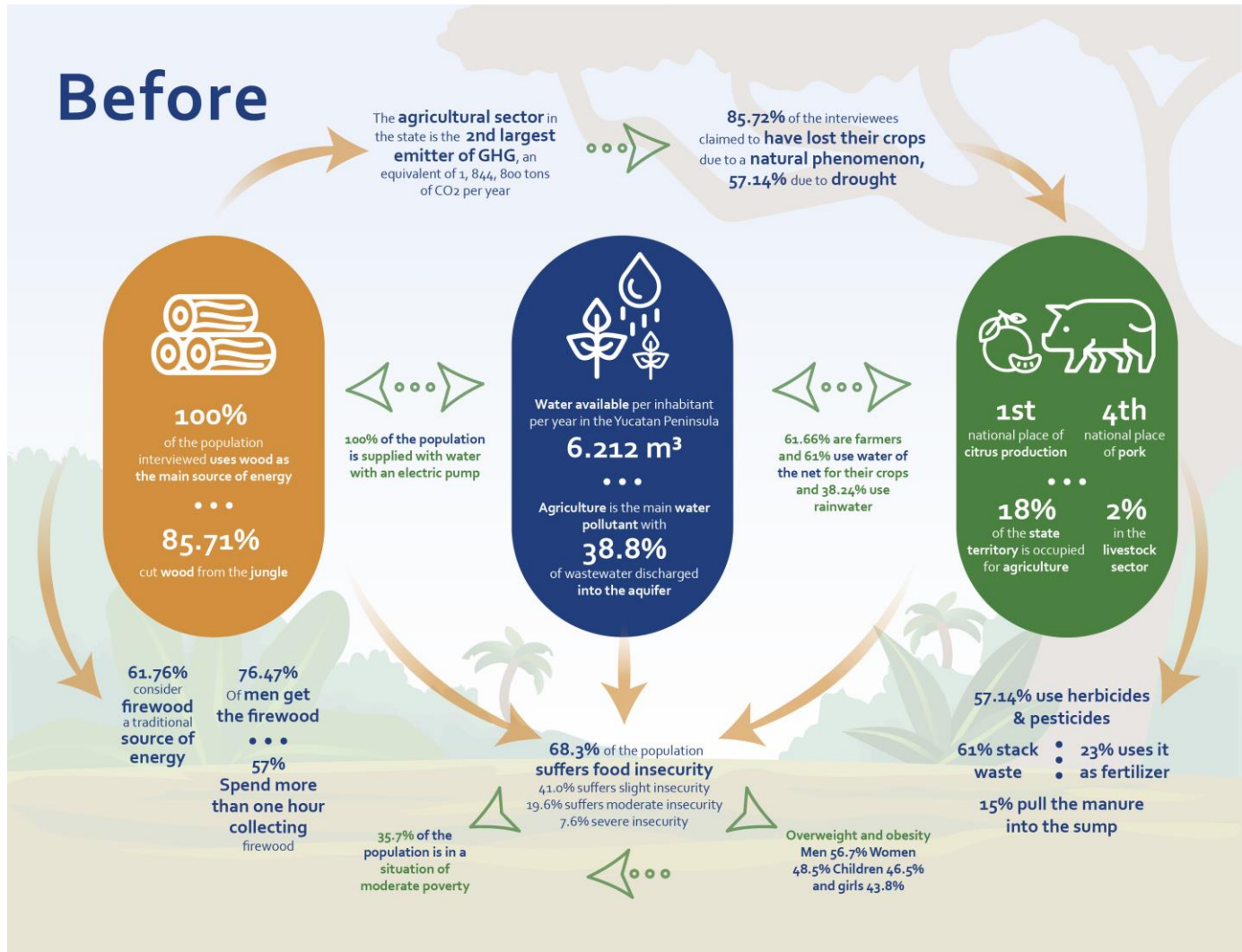


Figure 3. Water, energy and food nexus in the Yucatan communities, Original work of the International Renewable Resource Institute, 2019.

### The Biogas Program in the Yucatan Peninsula

The International Renewable Institute started the project in Yucatan in 2014, the objective of the Biogas Program is to provide local communities with tools to promote food security, understood by IRRI as the human capacity that allows constant access without physical, economic and social limitations to safe, nutritious, varied, sufficient, affordable and culturally

appropriate foods; produced locally through sustainable practices and self-consumption, whose use is ensured through food literacy and access to basic goods and services. In order to meet nutritional needs and preferences, a nutritional state of well-being, encourage local consumption, mitigate the extension of the agricultural frontier, and other negative impacts in the environment and reduce dependency on external inputs.

According to the problems and needs we found in the region and that are directly linked to the water, energy and food nexus, the Institute decided to use biodigesters to transform agricultural waste into an input to produce clean energy. These eco-technologies are containers that use animal manure and water to produce biogas (a reliable and clean source of energy), and bio-slurry, an organic fertilizer that displaces synthetic options.

The project is focused on solving the following problems and limitations:

1. Pollution of the groundwater sources with animal manure and synthetic fertilizers due to the karstic soil.
2. The lack of clean and renewable energy options resulting in the use of firewood for cooking and heating which implies a significant release of GHG, at the same time implies serious health risks when used inside households mainly for women, girls, and children, as well as time and energy invested in the collection of firewood.
3. Soil degradation due to agriculture, the use of agrochemicals and the need to extend the agricultural border.
4. Low productivity and crop quality due to soil degradation and erosion, as well as increased economic stress of families given the high costs of chemical fertilizers
5. High levels of undernourishment obesity and malnutrition in almost 50% of the population.

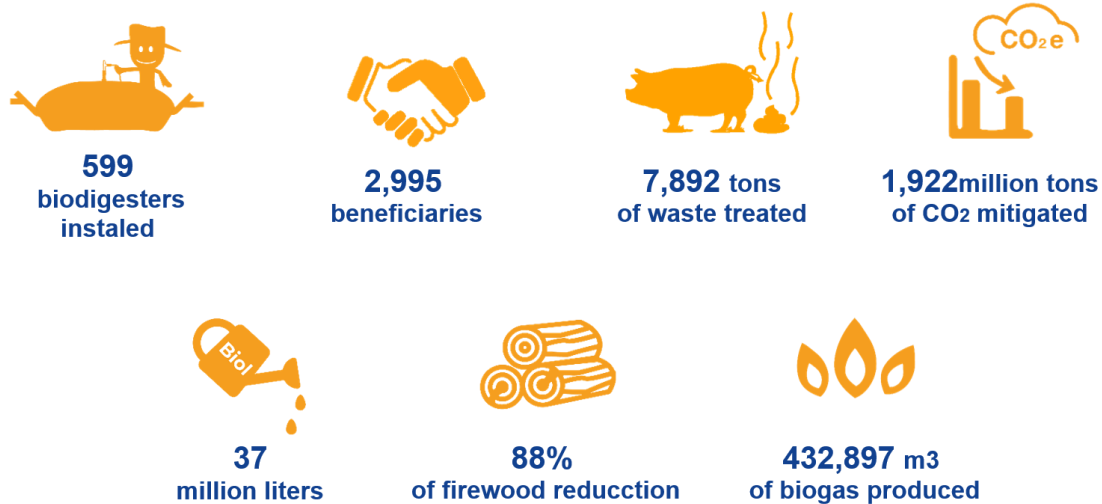
The economic stress of families, the lack of varied crops and high nutritional levels, the use of agrochemicals, the time and energy waste due to tasks such as gathering water and firewood, igniting the boiler and cleaning utensils in the kitchen, and the use of contaminated water, are factors that limit access and accessibility to varied, nutritious and culturally sensitive food for all. So this project has been dedicated to reverse these problems from a comprehensive proposal of solution that recognizes the complexity of the nexus.

The implementation process is focused on achieving the following goals.

1. The transfer of biodigesters for the integral treatment of waste and the production of biogas and biofertilizer.
2. The development of technical capacities in the final users of the technology for the correct and efficient use of biofertilizer and biogas.
3. Development of human capacities through the development of critical and systemic thinking, in order to promote agents of change for sustainability.
4. Creation of a collection, demonstration and research center of biofertilizer, to add value and develop local capacities of farmers around sustainable and regenerative agricultural techniques.

IRRI has installed a total amount of 599 biodigesters during a time lapse of 5 years in 44 Mayan communities of the Yucatan Peninsula, mainly in Mani, Tahdziu, Mama, Yazcaba, Cuzama, Valladolid, Dzan, Oxkutzcab, Tizimin, Tzucacab, Tekacx, Teabo and Chankom, with a total amount of 2,995 direct beneficiaries.

39% of the users of the technology are women, 35% are men; 13% are girls under 18 years old and 14% are boys under the same range of age. The main economic activity of these families is agriculture and women, most of them, are in charge of household activities.



Thanks to the emphasis we made in the capacity building component for farmers, almost 85% of the biodigesters are working, the rest of the digesters that are not working is because of a family emergency; these families see their animals as an investment and when they need money they sell their animals to have enough economic solvency to resolve the problem they are facing.

Also, 94% of the users of the technology will recommend the systems to their neighbors, and the main benefits they see in the technology are: 46% have access to a new and renewable source of energy, and 46% acknowledge savings in time, money and also generate new sources of income for their families.

### **Impact of the project: A change of the nexus**

After 5 years of the implementation of the Biogas Program in Yucatan we have seen significant results and changes in the water, energy and food nexus.

#### **Water**

With this project, using biodigesters as an integral waste treatment system, we have treated the manure of the animals of 599 farming families, avoiding a total of 7,892 tons of animal waste from going directly to the aquifer. Also, 11 percent of farmers have decreased their



use of synthetic fertilizers because of the use of biofertilizer, avoiding chemical pollutants go directly to the water sources.

Even though there is a lack of energy infrastructure to power the water pumps in rural areas, 88% of the farmers have enough water access for the biodigester, the other 11% does not have enough access during drought time but they use rainwater to activate the digester.

### **Energy**

41 percent of the population is using the biodigester to treat a 100% of the animal manure they produce, 26% use the digester and, with the manure that does not fit the biodigester (because it exceeds the system capacity) they are producing compost, 14% is still piling the manure that is not placed inside the biodigester.

The treatment of this manure is producing 432,897 cubic meters of biogas each year and it provides enough energy to cook 2 times a day with biogas, families have reduced their firewood consumption an 82% and due to the easy use of the biogas cookstove 38% of the families are getting involved in the activities that were considered only for women, mainly in cooking activities. Making a change in gender roles in the families.

### **Food production and gender**

The efficient management of agricultural waste is now producing more than 37 million liters of organic fertilizer, displacing synthetic fertilizers as well as nourishing the soil. 79.4 percent of the farmers have changed their agricultural practices, all of them because of the use of the biofertilizer produced by the biodigester and 88% of the farmers have perceived changes in soil fertility. Most of the families are applying the fertilizer in their backyard crops but some of them are also using them in their bigger parcels which is producing a higher impact of the project.

During these years we understood the key role of women in agriculture to ensure food security in rural communities. They represent a total of 80% of the workforce of the rural sector; nevertheless, their work is not recognized or remunerated.

In Yucatan, for example, women invest their time in cleaning their houses, take care of the house orchard: sowing, water the crops, fertilize, harvest, take care of their children and their education, prepare food for their family which



Lucy in Yucatán with her biodigester and her organic harvest.

includes also starting the fires to cook. And they are the ones that have less access to technology, financing, trainings and knowledge.

Climate change has bigger impacts on women and the complete family as it makes their time insufficient if they do not have access to clean water, if they have to walk longer distances to collect firewood, and if they do not have time to prepare nutritious food for their families. If their families are undernourished they have to spend money and time in the doctor, they are not able to go to school or to work, in these cases undernourishment causes poverty.

Women have a key role in sustainable food production model and in the nexus because if you gave women access to ecotechnologies and tools that help them in their daily activities, like biogas for cooking, instead of firewood they will have enough time to invest in the nutrition of their families reversing the cycle of poverty using resources efficiently and taking care of them to mitigate climate change.

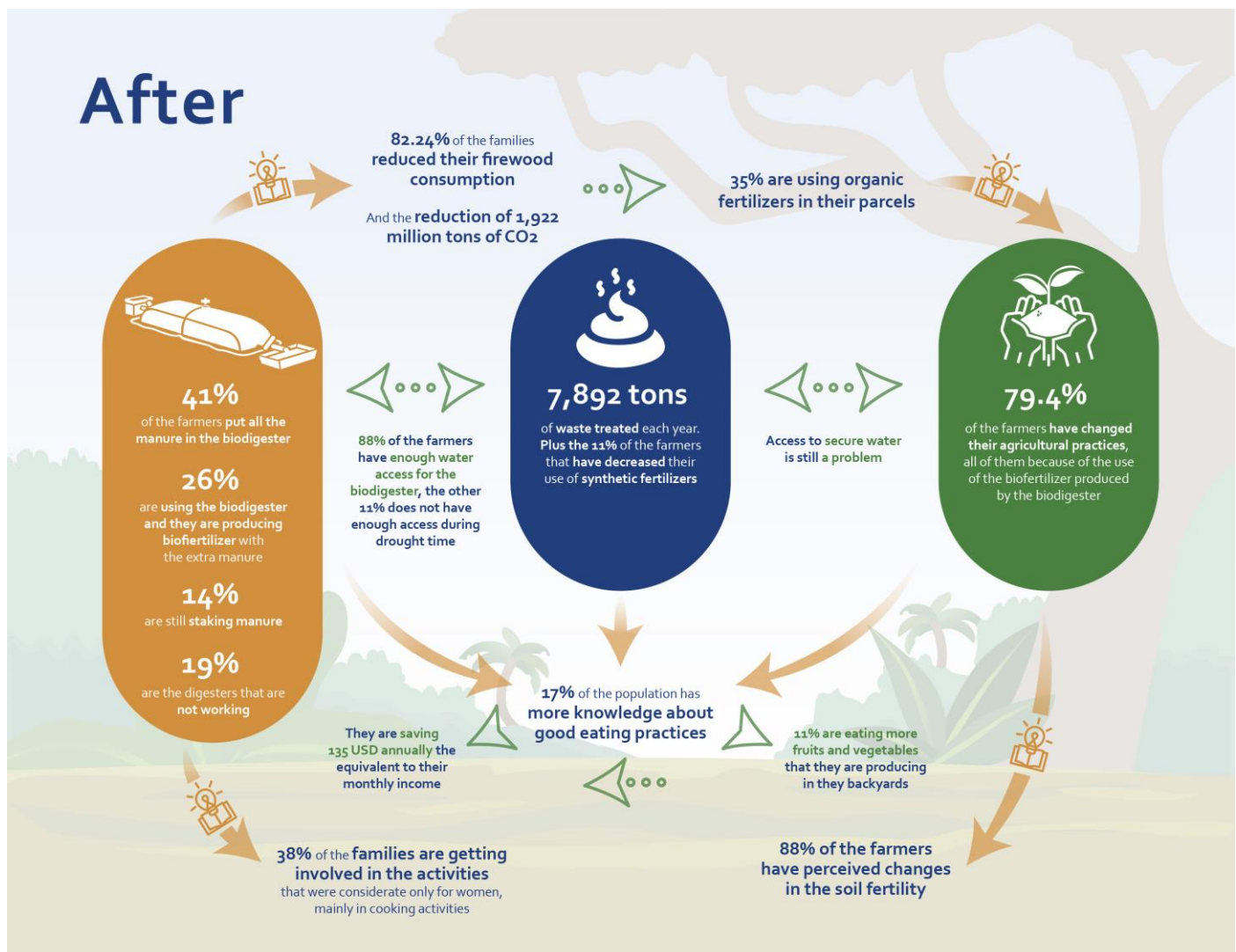


Figure 4. A sustainable nexus of water, energy and food nexus in the Yucatan communities, Original work of the International Renewable Resource Institute, 2019.

During the time of the Institute intervention, 17% of the users have acquired more knowledge on food alphabetization, 11% is eating more fruits and vegetables of what they produce in their backyards, and they have also saved an average of 135 USD annually by reducing their LP gas and firewood consumption, the equivalent to their monthly income, and now they are investing that money on their kids' education.

Lucy and her family are one of the most interesting cases in Yucatan, she and her husband Rudy are smallholder farmers in Mama, Yucatan, they were of the first beneficiaries of the Biogas Program in the region. They started to use the biodigester and they are one of the families that are taking more advantage of the biofertilizer, they saw the results in their crops and they started harvesting more fruits and vegetables.

Biofertilizer allowed them to protect the soil of their garden, with a stronger soil they didn't need to use synthetic agricultural inputs, and they started to produce more. That was the reason why they decided to start selling the surplus in the organic market, all the family members participate in the business. Lucy and her husband Rudy were able to pay their sons education; they are both studying agriculture in public universities and they both want to keep the family business.

### **The Challenges**

At the beginning of this project, one of the challenges that the Institute faced was the cultural barriers of the farmers to the adoption of new technologies, most of them couldn't believe that they will be able to produce a safe and reliable source of energy from manure, but as they started to see their neighbors results, they started to trust in us, to trust the project.

Farmers like Lucy and Rudy were key parts of this project, their work made other farmers interested in the new technology, made them want to try new agricultural practices. They helped us to make some demo-events in their farms, so their neighbors could be able to see how the system was working, that is safe to cook with biogas, and that it has no smell or other risks.

Now there are 11 networks of organic farmers in Mama, where Lucy and Rudy family live, and the change of gender roles in the families is remarkable; they are a team and they all participate in the food production activities and in the organic business management and enjoying individually of the economic benefits, taking advantage of



Lucy, Rudy, their son and IRRI team in their crops in Yucatan.



the knowledge of each member. We can see these changes in the 11 families making a stronger, resilient and solidary community.

We are also dealing now with the challenge of working with women; we work with them to make them feel confident and empowered with the use of technology, we support them so they can have enough time to develop their human capabilities and also to recognize the important work they are doing every day by diversifying their employment and income options.

Another challenge and one we keep working on is how we make easy to communicate the technical part of the biodigester management, how can we make it clear for all the family members so it is not just a one family member activity and all the family can get involved. To improve that we created a biofertilizer research and training center U Ka' Muuk' Lu'um, the second force of the soil in Mayan, a biofertilizer collection center where we collect the surplus of the biofertilizer that farmers are not using to create other kinds of supplements like compost, vermicompost or biochar to improve the soil.

The biofertilizer collection center also works as a demonstrative center of other ecotechnologies, they work with an experimental orchard fertilized with the organic supplements that they create on site, they have a seed bank and plant reproduction.

### **Capacity building as a key element**

Since the beginning of the project we knew that ecotechnologies does not have a significant impact if they are not accompanied of training, so that families and farmers can include the technology to their daily routine and make them part of their lives, adapting it to their culture and traditions.

IRRI created the U Ka' Muuk' Lu'um center with the support of some of the community members that are participants of the program. U Ka' Muuk' Lu'um also functions as a capacity building center where Mayan communities are learning how to increase local food production in an organic and sustainable way, food alphabetization, the adoption of other technologies, in sum a center for the local exchange of good practices, lessons learned and experiences among producers that includes a rigorous research component for validation. During the last monitoring of the project (March 2019) we saw an increase of the number of families that are giving correct maintenance to the system, this is due to the continuous and systematic trainings offered at U Ka' Muuk' Lu'um.

Therefore, by providing farmers with ecotechnologies and local capacity building, the interaction of the nexus can be transformed into a sustainable model of development; protecting natural water sources, generating safe sources of energy and increase food production in a sustainable way according to cultural and local needs.

This tools for farmers are changing the game, they are giving new opportunities to the communities with new sources of decent employment, at the same time, they represent climate change mitigation and adaptation practices, our work aims to see more families like Lucy and Rudy with an income that allows them pay for their son's education and that also that education seeks to reduce migration, valuing the work of smallholder farmers as the main engine of the world, because if the field is abandoned by hundreds of kids looking for a unskilled job in the cities what are we going to eat?

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