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Dynamic conservation of genetic resources: Rematriating the maize landrace *Jala*

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Abstract

The conservation of landraces is fundamental to safeguarding crop diversity and hence, food security and sustainable production. *Jala* is a special maize landrace from the Jala Valley of Mexico and has the largest ear and tallest plant of all maize landraces in the world. However, changes in economic and environmental conditions have transformed the valley and numerous factors now threaten its inhabitants and the world with the genetic erosion of this ancestral landrace. This study outlines the sequence of events in the history of *Jala* and at the same time describes the evolution of strategies of complementary *in situ* and *ex situ* conservation of maize genetic resources. The concept of rematriation and the dynamic conservation model behind it are discussed and applied to the specific context of *Jala*. Rematriation could be instrumental in the creation of an enabling environment for the dynamic conservation of maize landraces and reverse the genetic erosion of traditional cultivars in Mexico.

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Acronyms

CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
FAO	Food and Agriculture Organization

1. Introduction

Maize is intricately entwined with the cultural identity of Mexico. The country has at least 59 different major landraces of maize (O'Leary 2016, Wellhausen and Roberts 1951). The conservation of landraces is not only essential for safeguarding crop diversity but also for sustainable development in rural areas. Landraces have particular agronomic and consumption traits that contribute to food and nutritional needs and are adapted to the cultural diversity of communities (Maxted et al. 1997, Shiva 1994, Rao and Hodgkin 2002, Ford–Lloyd et al. 2011, Maxted et al. 2012). The genetic structure of landraces has been shaped by evolutionary processes and by farmers' selection and management practices over generations of cultivation and adaptations to changing environments. They are also an integral part of the diets and rituals of many communities (Smale et al. 2001, Altieri and Merrick 1987, Brush 2000). In addition, landraces harbor unique genetic information that can be used for breeding modern varieties that are resistant to certain pathogens and pests, leading to yield gains and improved crop performance (Hearty and Ellstrand 2016, Smale, Bellón and Aguirre-Gómez 2001).

Many landrace varieties have been proven to be resilient to agro-climatic pressures over the centuries. Some improved maize varieties and hybrids cannot thrive in challenging environments. Nevertheless, changes in consumer and market preferences, particularly with younger generations, pose challenges to maintaining the diversity of maize landraces in the communities. The report presents the case for the maize landrace *Jala* maize and a proposal on how seed rematriation can promote the utilization and conservation of this landrace.

The objective of this report is twofold: 1) elaborate the concept of rematriation and its relation to the use and conservation of plant diversity, taking the case of the *Jala*, as an example, and 2) present a general model of rematriation for the preservation and utilization of landrace varieties.

In the contextual section, we describe the study site and a sequence of events that juxtaposes the history of the *Jala* and the evolution of the conservation and utilization of plant genetic materials. Section 3 presents the methodology that combines the proposed conservation approach and the application to *Jala*. In the results section, we discuss the circular model of dynamic conservation, outline the challenges of *in situ* conservation, and highlight the seed rematriation story of *Jala* and how it promotes the utilization and conservation of this landrace.

2. Context

2.1 Description of the study site

The municipality of Jala is located in the south of the state of Nayarit (Figure 1) and has a total population of 17,698 inhabitants (in 2010) (INEGI 2013).The town is located at the foot of the Ceboruco Volcano and is bordered by the following municipalities: Santa María del Oro, La Yesca, Ixtlán del Río and Ahuacatlán. Jala is traversed by the Guadalajara-Tepic highway connecting it with the Pacific Ocean.

Jala municipality is known elsewhere in Mexico for its giant maize landrace, known by local farmers as *Jala* or *maíz de humedo*. The *Jala* is recognized as the maize with the longest ear and the tallest plant in the world and it is one of the 59 traditional Mexican landraces (CONABIO 2016). The name of the landrace derives from the name of the valley where it originated (Kempton 1924, Wellhausen and Roberts 1951). More precisely the name Jala means the place where sand abounds and it is derived from the Nahuatl[1] word *Xali*, which means "sand," and the variant *Tla*, which means "place where it abounds."

Although the municipality has 54 small towns (*localidades*), *Jala* is currently cultivated only by a small number of farmers in the towns of Jala and Jomulco located in the valley, and by a smaller group in the vicinity of the Ceboruco volcano, in the community of Coapan (A. Hernández-Guzmán 2007). An estimated 60 percent of the Jala municipality is covered by hilly areas where the famous Ceboruco volcano is located. The remainder (40%) is represented by semi-flat and flat areas, which is where *Jala* is grown and the towns are located. The temperature fluctuates between 16 and 28°C, the precipitation between 700 and 1400 mm, and the altitude vary from 300 to 2500 meters. The weather is semi-warm, sub-humid with rain in summer and medium humidity (46.84%). The special microclimate is warm and sub-humid (Inafed 2017), and with soils full of nutrients due to the ashes and lava deposits left in the ground after the three volcano eruptions (Nelson 1986). Kempton (1924) claimed that what allowed this landrace to attain its full potential was the valley's very fertile, light and porous soils attributed to the volcano. Maize producers perceived it similarly:

[1] Nahuatl is a macro-language uto-aztecas spoken in Mexico (RAE, Real Academia Española 2005)

"The *Jala* will only grow in some places in the Jala valley, only the places that are blessed enough and have the special conditions to grow"	"el maíz de húmedo solo crece en algunos lugares del valle de Jala, solo los lugares que son lo suficientemente bendecidos y tienen las condiciones especiales para que él pueda crecer"

Male *Jala* producer, 40-45 years old

Maize was inherited from the pre-Hispanic ancestors that populated the area and is still a very important element in the culture of the people in Jala. Today one can observe various objects around the municipality that demonstrate how this landrace is embedded in the culture of Jala and represents an identity icon for the people. For instance, the figure of the *Jala* can be found in the plates of the names of the streets or in the Jala municipality's coat of arms (Figure 2).

Jala and the Jala Valley were chosen as an example for three reasons, 1) *Jala* stands out among other maize because of its unique traits and attributes, 2) *Jala* is part of the culture and identity of a community, and 3) Jala municipality is located in a defined area in which the maize is endemic. The size of the ear and the plant of *Jala* makes it easy to recognize in the Jala valley (Rice 2004). As an example of a landrace that is cultivated in a small and defined area and is now in danger of extinction, the story of *Jala* can generate public awareness about the risk of losing valuable landraces (Costich 2015). More than providing food and economic means, *Jala* is part of the culture and identity of people. As mentioned by Costich (2015) "the *Jala* landrace will always hold a special place in my heart, not just because of its size, which is impressive, but also because of the culture surrounding it and the dedication of the people who grow it".

2.2 History and evolution of *Jala*

The history and evolution of *Jala* reflects how the discourse on genetic resources conservation evolved during the 20th century. Plant genetic diversity conservation has been of vital importance for agricultural development. Since the beginning of agriculture, humans have selected plant varieties for domestication and for desired traits and conserved them as the crops that we know and eat today (Day-Rubenstein, et al. 2005). Farmers (and their families) have been the main crop conservers and traditional breeders for centuries. One of the results of these processes is the *Jala*, the largest landrace in Mexico. This maize has been bred and produced in the early pre-Hispanic times in the Jala municipality, Nayarit Mexico, where people were devoted to it. The earliest evidence of the giant maize can be attributed to the iconic Assumption Virgin Mary, patron saint of the municipality, which according to the legend the size of the opening of her arms is as large as a *Jala* ear (Figure 3). The original statue of the Assumption Virgin Mary is located in the Lateran Basilica of Our Lady of the Assumption built in the 17th century in the town of Jala (Inafed 2017).

At the end of the 19th century, the need for genetic conservation was also recognized scientifically in the fields of forestry and agriculture (Cieslar, 1899, cited in Langlet 1962). Since then, the conservation of plant genetic diversity shifted from being a rural tradition to a scientific, environmental, social (ethical) and economic discourse, involving different disciplines and evolving across the years. Two main strategies for conserving plant genetic resources can be found in the literature, *in situ* and *ex situ*. The Convention on Biological Diversity (UN 1992) defines the two strategies as follows:

> "***In situ*** conservation: mean the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties"

> "***Ex situ*** conservation: the conservation of components of biological diversity outside their natural habitats"

For landraces of cultivated crops, *in situ* conservation occurs on farms under the seed and crop management of farmers. While *in situ* conservation allows plants to continue to evolve genetically in response to human management and environmental and social changes, *ex situ* stops dynamic interaction between gene complexes and the environment by isolating the genetic material in long-term storages. Both of them helping to ensure the long-term conservation of germplasm.

Following the sequence of events, agricultural industrialization began in higher income countries between 1900 and the 1950s, when breeders from private and public institutions sought to develop new varieties with better adaptation and higher yield to supply the increasing demand for food and fiber (Pistorius 1997). Plant materials from the different diversity centers were obtained through international exchange, purchase or by domestic and foreign explorations (Hyland 1961).

An example of an exploration was that led by Kempton (1924), who was the first researcher to write about *Jala* in the scientific literature. He and his colleagues claimed to have known *Jala* since 1907. The author referred to it as a "truly gigantic" type of maize, with a plant of 20 feet (6.096 m) high, and ears of 21 inches (55.88 cm) long and a circumference of nine inches (22.86 cm) (Kempton 1924). To illustrate the length of the plant, several researchers mentioned that farmers harvested on horseback to reach the tall ears, carrying the ears back bundled like logs on the back of burros (donkeys) (Kempton 1924, Tibon and Beltran 1979, Rice 2004, Hernandez-Guzman 2007). According to Kempton (1924), *Jala* was the predominant landrace in this valley during the first half of the 20th century. This was not only described by the researcher, but it was the perception of farmers as well, as indicated by the following quote:

"The Jala landrace had always been in this valley, this was the maize from my grandparents' grandparents"	"El maíz de húmedo siempre ha estado en este valle, fue el maíz de los abuelos de mis abuelos"

Source: Group of *Jala* producers

During the first half of the 20th century, around 700 and 800 acres (283 and 324 ha) were dedicated to *Jala*, composed of small individual holdings planted in a community way[2] (Kempton 1924). Despite the fragmented landholdings, *Jala* was planted in blocks in the valley, conserving the landrace and protecting it from genetic variability triggered by open pollination and genetic drift. In addition, at that time, the Jala valley was partially isolated as no proper roads were connecting it to other cities. Jala was "sixty miles (96.6 km) southeast of the city of Tepic and a few hours' journey by mule back from the rail line now under construction by the Southern Pacific of Mexico." (Kempton 1924, 343).

Despite the importance of centers of crop diversity, such as Mexico for maize, in the first half of the 20th century the world's conservation of plant genetic materials was accomplished by industrialized and high-income countries. At that time, the scope of the collections was restricted, and the exchange of information and material was limited. Both the collections and the documentation of the plant genetic material were focusing on how to help breeders to use them, rather than concentrating in the conservation of biodiversity per-se (Pistorius 1997). This could be observed in the article from Wellhausen and Roberts (1951), a classification of the Mexican maize diversity. More than representing a classification for scientific knowledge, the article focused on informing plant breeders about the morphological and physiological characteristics of 59 races of Mexican maize, including *Jala*, recognized as the longest one (Wellhausen and Roberts 1951). The researchers mentioned that the length of the *Jala* ear could range between 45 to 50 cm.

[2] Mexican revolution in 1917, Mexican agriculture has been characterized by large amounts of land in collective land holdings called ejidos (Rice 2004)

As concluded in the 10th Session of FAO Conference in Rome, November 1959, efforts to conserve landraces became more important as they were a great source of genetic diversity for breeding (Pistorius 1997). Hence landraces started to be part of *ex situ* collections. Until 1950s *Jala* landrace was conserved *in situ* by farmers and communities, however shortly after scientist recognized its potential a sample of this landrace was collected and conserved as an accession in a genebank (Hernández-Guzmán 2007).

One of the first signs of industrialization in the Mexican agriculture was the creation of CONASUPO[3], a parastatal company with the aim of promoting economic stability in the countryside (Ochoa 2000). It was established in 1961 in order to guarantee the purchase and regulation of prices in products of the basic food basket, particularly corn. Although it started in 1961, CONASUPO arrived at Jala in the mid-1970s. The arrival of CONASUPO changed the market dynamics of rural areas and led to a decrease in the production of maize for subsistence production (Rice 2004). Only certain maize varieties were bought through the CONASUPO program, limiting the market for landraces and standardizing market prices. This means that all maize varieties should be sold at the same price. Uniform prices led Jala farmers to replace their maize landraces with higher-yielding maize varieties and also to diversify to other cash crops, such as tobacco, sugar cane and vegetables (Hernández-Guzmán, Interview to curators 2018). The political decision adversely affected the market for maize landraces and has been one of the classic examples of genetic erosion triggered by the replacement of local varieties by modern varieties. This was confirmed by one of the producers interviewed when he said:

"the price is fixed by government policy, that is the price payed by traders, and they can even pay less but never pay more"	"El precio lo fija la política del gobierno, sobre ese precio pagan los comerciantes y pueden incluso pagar menos pero nunca pagan más."

Male *Jala* producer, 65 years old.

At the beginning of the 1970s, a different discussion regarding the exploration and conservation of genetic resources emerged (Frankel and Bennett 1970). At the FAO/IBP[4] Technical Conference on

[3] CONASUPO: in Spanish "Compañía Nacional de Subsistencias Populares", in English "National Company of Popular Subsistences"

[4] International Biological Programme (IBP) is a global initiative focused on fundamental biological issues published in 1966 a categorization of plant resources in cultivars (landraces and cultivars with special connotation), wild relatives of

the Exploration, Utilization and Conservation of Plant Genetic Resources in 1967, scientists concurred that genetic erosion was increasing and there was limited availability of genetic resources. In addition, *in situ* and *ex situ* approaches were seen as alternatives or even substitutes for one another. Until the late 1980s and early 1990s, *ex situ* was recognized as the dominant conservation strategy in the scientific community (Pistorius 1997). The research questions were more related to the management of genetic resources; there was a need to conserve materials as long as possible and to establish a more systematic utilization of the genetic resources by the breeders (Berthaud 1997).

Nevertheless, the rate of genetic erosion drew attention to the need to implement conservation strategies. As is the case of Carlos Octavio Carrillo Santana, President of the Municipality of Jala, who in 1981 came up with an idea of implementing “the largest ear of corn in the world contest” to encourage farmers to conserve *Jala in situ* (Listman and Pineda 1992). Since then, the contest takes place every year on August 14 and is one of the most popular events during the week-long celebration in honor of the town’s patron saint, the Assumption Virgin. During the contest, farmers that produce *Jala* maize bring the three longest ears from their harvest and compete to see which one has the largest ear. The three farmers with the largest ear receive prizes, but the pride and satisfaction from winning the contest exceed any economic or in-kind incentive. Figure 4 shows the winner of 2018’s contest a young man with a very happy face next to his proud father (on the right). The contest is a space were farmers can showcase their efforts in cultivation and highlight their important roles of being guardians of the *Jala* maize and the culture embedded in the landrace.

By the end of the 20th century the discourse turned toward novel ways to use genetic resources, and the contribution that this can make to socioeconomic development and food security (Cooper et al. 2001). For instance, during the 1996 World Food Summit political leaders committed to reduce the number of undernourished people and “to pursue, through participatory means, sustainable, intensified and diversified food production” (FAO 1996). The change of centuries represented a transition for the utilization and conservation discourse, from a centralized vision to a more decentralized one. For example, a broader definition of “users” of plant genetic materials was proposed (both breeder and farmers were included) and *in situ* and *ex situ* approaches were recognized as complementary methods (Smale et al. 2001, Brush 2000, Maxted et al.1997). Lastly,

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domesticated species and, wild and semi domesticated species, setting a standard in discussions in the conservation of genetic resources.

while the coordination of global conservation efforts was still a goal, the scope expanded to incorporate local, national, and regional activities.

3. Methodology

3.1 The circular model

The complexity of the utilization and conservation of plant genetics discourse increased during the beginning of the 21st century, when scientist realized that both *in situ* and *ex situ* conservation played very important roles (Maxted et al. 1997, Brush 2000, Smale et al. 2001, Hawkes et al. 2012). To achieve a complementary and holistic approach, a series of new relationships between farmers and breeders, as well as between users and managers of genetic resources needed to be introduced. Researchers realized that conservation involved a series of complex social, political, biological and genetic issues and therefore more interdisciplinary approaches were needed (Rice 2004). One important element from these models was comprehending farmers' decision-making process regarding germplasm conservation and utilization, and their relationship with genebank managers, breeders and other stakeholders. A particular model that we would like to discuss is called the *circular model*, which was initially proposed by Berthaud (1997) but interpreted and followed by others (Hawkes et al. 2012, Tin et al. 2001, CIP 2015, Piergiovanni and Laghetti 1999, McLean-Rodríguez et al. 2019, Enjalbert et al. 2011).

The *circular model* is suitable because it describes the complementary uses of *in situ* and *ex situ* conservation methods and how this complementarity creates a dynamic cycle in the utilization and conservation of plant genetic materials. Berthaud refers to a *circular model* of genetic resources when an evolutionary conservation strategy is coupled with a static conservation process, generating a cycle of germplasm exchange were both utilization and conservation are happening (Berthaud 1997). Through this model, materials that traditionally has been conserved by local communities are shared within the community and among neighbor communities and are made widely available for other potential users (i.e. farmers, researchers and breeders). More importantly the circular model is a strategy to assure maintenance of genetic integrity.

As identified by several researchers, most of the remaining agrobiodiversity conserved *in situ* is found in the semi-subsistence farms of emergent countries or in the "home gardens" of the industrialized nations, providing the communities that grow them with food security within their households (Brookfield 2001, Brookfield et al. 2002, IPGRI 2003). Landraces conserved in local fields have the capacity to support more rare alleles and different genotypes, representing a source of valuable materials for crop development (Berthaud 1997, Brown 2000, Berthaud and Gepts 2004). However, certain varieties that have a higher productivity and commercial potential are displacing the traditional landraces, reducing the available diversity in the process, and indirectly increasing the risk of food insecurity (IPGRI 2003). In addition, maintaining varieties with low economic value through *in situ* conservation is unlikely, hence they are good targets for *ex situ* collection and conservation (Smale and Bellón 1999). However, local varieties with high present and future economic value should be prioritized through *in situ* approaches.

In order to ensure the long-term conservation of these unique germplasm, *in situ* conservation should be complemented with *ex situ* methods. Having a dynamic conservation step in the model can protect varieties from unpredictable evolution and serve as a backup for future events. Varieties conserved *ex situ* could be reintroduced in the fields when needed, either in their place of origin or in new sites. Furthermore, having these accessions in genebanks make them available to germplasm users, promoting private and public research, as well as promoting their adoption in foreign countries (Cooper, Spillane and Hodgkin 2001). By having a circular system of exchanges, evolution for material conserved *in situ* and *ex situ* could be maintained at the same pace (Berthaud 1997). Testing this diversity under different agro-ecological conditions and conserving them for a long term in *ex situ* facilities will represent a large benefit both in terms of protection of diversity and agricultural development.

Therefore, any effort should be an approach that leads to integrated conservation (Enjalbert et al. 2011), i.e. a balance between *ex situ* and *in situ* methods. The approach should be holistic and enhance the cooperation between different parties, such as scientists, farmers, and indigenous communities. Farmers and indigenous communities are particularly important because they hold the traditional knowledge and cultural heritage that is embedded in these landraces in providing a more reliable source of food, feed and fiber for the rest of the world (Berthaud 1997).

3.1.1 Seed rematriation, an application of the circular model of dynamic conservation

Scientists at the International Center for Maize and Wheat Improvement (CIMMYT)[5] are fostering the *rematriation* process, a *circular model* to enhance the dynamic conservation and utilization of traditional maize land races in Mexico, such as *Jala*. The *rematriation* process is a way for genebanks

[5] Dr. Denise Costich and Dr. Carolina Camacho are leading the work on rematriation at CIMMYT -- acronym in Spanish means El Centro Internacional de Mejoramiento de Maíz y Trigo.,

to build a more integrative, collaborative, and respectful partnership with producers and promote *in situ* conservation among agricultural biodiversity growers.

In social development and political studies, researchers make a difference between ethnic and cultural identity and political and territorial identity. Fuentes-Pérez (1997) expressed that fatherland (*patria* in Spanish) is the combination of two elements nation (the people) and the country (the territory). The fact that an exile (or expatriation) of someone is the split from its country, or original territory, but not from the nation – the communion of the people, culture, tradition, history – implies that wherever we are is where the nation is, independent of our presence or absence of the country (Fuentes-Pérez 1997). Similarly, Choi (2001, 129) explained that Koreans in China felt they have dual identities "as Chinese nationals with Korean blood lineage", distinguishing political identity from ethnic identity. For them, motherland (*matria*) represents the country from which they came (in this case Korea), their ancestral land, and fatherland (*patria*) represents where is the base of their lives and where their political and practical circumstances happen.

Let us consider the following analogy in terms of germplasm and their method of conservation. A seed that has been maintained in its motherland (*matria*) means it has been conserved *in situ*, whereas a seed that has been safeguarded in a genebank or *ex situ* is parallel to being in the fatherland. Consequently, according to Camacho and Costich (2018)

> **Repatriation** is the formal transfer of germplasm between institutions in which an institution reintegrates/returns an element or a collection to a receiving institution which has a formal representation in the territory of origin of the germplasm. On the other hand,
>
> **Rematriation** is the co-creative process of engaging with a community of farmers, including indigenous people, to transfer germplasm conserved in an *ex situ* collection to its place of origin where it can also be conserved *in situ*; where a nurturing environment is co-created to utilize the landraces for inclusive and sustainable agriculture and led economic growth.

Therefore, while an accession that has been maintained in a foreign genebank is returned to its local or community genebank is call *repatriation*, an accession that is returned to its land of origin to continue to be conserved *in situ* refers to *rematriation* (see Figure 5).

Equally important, the concept of rematriation has been used in the indigenous cosmovision as the process of returning the seeds to the Mother Earth, to their home.

> "Mother Earth is reclaiming of ancestral remains, spirituality, culture, knowledge and resources" (Muthien 2011, cited in Kailo 2012).

> "Rematriation; This term describes an instance where land, air, water, animals, plants, ideas and ways of doing things and living are purposefully returned to their original natural context–their mother, the great Female Holy Wild [...] any attempt to 'rematriate' them back to the Holy in Nature is the beginning of cultural sanity and healing" (Prechtel 2012)

The seeds will come back to mother earth where they will be nourished and protected, resulting in food that will be eaten by the family that produces it or the ones that buys it.

> "Seeds waiting for loving hands to patiently place them into welcoming soil once more so that they can continue to fulfill their original agreement to help feed the people". (White 2017)

Hence rematriation not only refers to returning the seeds to its origin but restoring ancestral traditions in forms of agricultural and cultural practices. A landrace is not only a set of genes resulting from the impact of natural selective forces but is also the result of a voluntary intellectual construction (Bellon 1996).

3.2 Method: data gathering for the Jala rematriation project

The information for the Jala rematriation project was gathered though systematic literature review and from the analysis of qualitative primary and secondary socio-economic data. For the primary data, we conducted semi-structured interviews and focus group discussions with different stakeholders involved in the *in situ* and *ex situ* conservation of this landrace. First, we conducted semi-structured interviews to scientists (see Table 1) from different institutions in Mexico. Second, young individuals (15-29 years) from the Jala municipality were gathered into three different focus groups to understand their views regarding the conservation of *Jala* and other landraces. Five structured surveys and five informal talks were conducted with consumers around Jala municipality and Ixtlan del Rio. The respondents were randomly selected from markets and plazas[6]. Lastly, semi-structured interviews

[6] Markets and plazas were selected because these are the locations were people usually buy maize.

were conducted with *Jala* producers who were living and growing *Jala* in the towns of Jala and Jomulco. These were drawn from a list of seed donors (see Table 4). Eight interviews were conducted, each lasting from one to two hours. The secondary data were provided by CIMMYT and consisted of data collected by Rice in 2004 and Camacho and colleagues in 2017. Lastly, articles published in scientific journals and documents provided by CIMMYT were reviewed. The qualitative data were analyzed using content and narrative analysis and descriptive summaries.

4. Results

4.1 The importance of the *Jala*

Jala is an essential part of the cultural and tradition of the Jala community. In section 2, we described how the landrace is part of the daily life of this community; in this subsection, we highlight the associations and perceptions expressed by particular groups about this maize. We focus the analysis in understanding the role of the family and its members in the production and commercialization of *Jala*. Household head and *Jala* the producers, most commonly men that have been passing the agricultural technical know-how among generations; women and mother, who transform maize, participate in variety selection, and confer food culture; and youth, who represent the future of this system. We summarize the perceptions of these groups and their respective roles in the conservation of *Jala*. Without the interaction and existence of these three groups, the conservation of this landrace will not be possible.

First, we have the *Jala* producers – who are generally more responsible for caring for and reproducing the seed of *Jala* over the years. They knowledge of the best growing conditions for the landrace. Generations of farmers have been in charge of breeding this maize into what we know today. *Jala* used for food (i.e. the ear and grain) is mainly marketed locally and has low grain yield compared to other landraces and varieties. It is difficult to find local consumers who are willing to pay a premium price for *Jala*. In spite of the above, some of the farmers continue to conserve the seed and plant the maize. Researchers have found that the farmers' demand for maize landraces is shaped by different attributes and not only yield and costs (Smale et al. 2001). Farmers account for non-market values that influence their response to changes in the market price of maize and thus to on-farm conservation (Arslan 2011, Arslan and Taylor 2009). In the case of the *Jala*, one of those non-market values is the fact that farmers perceive that conserving *Jala* seed is part of the legacy their ancestors left them, as can be inferred from the following quotes

"[My father] inculcated us to take care of this seed, and he told us that we should never sell this seed or lose it" "not everyone has *Jala*"	"[Mi padre] a nosotros nos inculcó cuidar esta semilla, y nos dijo nunca se les vaya a ocurrir vender esta semilla o perderla ustedes síganla." "no cualquiera tiene maíz de húmedo"

Male *Jala* producer, 52 years old

"I had the possibility to leave [Jala], but I didn't, that's why these are my lands, the lands that my parents had. If I had left, maybe when I arrive, all the lands would be infected [referring to the use of chemicals], that is too much risk."	"Tuve la posibilidad de dejar [Jala], pero no lo hice, es por eso que estas son mis tierras, las tierras que mis padres tenían. Si me hubiera ido, tal vez cuando volviera, todas las tierras estarían infectadas [refiririendose al uso de químicos], eso es demasiado riesgo"

Male *Jala* producer, 52 years old.

"I will always defend the flavor of this corn [referring to *Jala*]"	"siempre defenderé el sabor de este maíz [refiriéndose al maíz de húmedo/ Jala]"

Male *Jala* producer, 65-year-old.

These statements reveal that the traditions and legacies of ancestors are still well rooted in the perspectives of farmers who grow *Jala*. Some farmers narrated what they heard from their grandparents, for example, how eating a *Jala* ear represented freedom and how it was served in special occasions, such as family reunions. One of the farmers remembered that his grandfather used to explain to him that during the times of the big haciendas, peasants gave all their production to their owners and could only eat restricted crops. For the landowner family (*los hacendatarios*) was common to eat the tender cobs but it was not the same for peasant. For the grandfather of this producer being able to have a farm of his own and consume what he produced was freedom, that is why eating the ear of *Jala* was very important. Others talked about their own experiences – how they used to play using two maize stalks to make stilts and pass the streams. Finally, they recalled that the long and strong maize stalks were used as fences (or *Chinamis*) to confine pigs, as support for houses' walls, and to make roofs. These additional non-market values add a shadow price to the market value of *Jala* and explain why farmers among the groups of people continue to plant the crop and conserve the seed *in situ*.

Non-market values are also perceived and transmitted by women to their husbands who are the principal producers of *Jala*. In Jala, some women participate during sowing and harvesting of maize, including post-harvest activities such as threshing the cob, packing the grain or cob, and the selecting the seed for storage. Even though women do not always participate in agricultural production process, they transform and process the harvest, prepare a range of special dishes made of *Jala*, and care for household members. Women check the storage where grains and seed are kept, collect the ears which will be cooked, and indirectly care for the seed during the storage time. In addition, as mentioned by several *Jala* farmers, men select the maize variety for commercialization and women select the varieties that will be consumed in the household. Consequently, if women decide that *Jala* landrace is important for their family nutrition and it is flavorful, their husbands will plant it. Women have the power to conserve and protect the *Jala* and to transfer that knowledge to their children.

"The work of women is to sensitize. The woman in general is a mother, regardless of whether they have a son/daughter or not, the commitment should be to motivate their relatives or other children. I, as a woman, am doing it."	"La labor de las mujeres es sensibilizar. La mujer en general es madre, independiente mente si tienen hijo o no, el compromiso debería ser motivar a los parientes o a otros chavitos a otras personas yo como mujer lo estoy haciendo uno como joven no lo vas a hacer."

Female *Jala* producer, 41 years old.

Lastly, we have the young men and women who are the next generation of maize farmers and guardians. Unfortunately, the expectation that this happens are very low among current producers. Although there are young people who are interested in continuing in the business of agriculture, the focus naturally is on market prices and farm profit maximization. Non-market values are not appreciated as much and they continue to lose motivation to plant *Jala*.

"I try to inculcate them [the importance of conserving *Jala*], but they tend to focus	"Yo intento inculcarles [la consrvación de el maíz de húmedo], pero allí cada quien agarra sus pensamientos, con sus estudios buscan

on their studies they look for other things, in the culture of money.”	otras cosas, en la cultura de dinero.”
“The young people are leaving and looking for other things that give them more money. It is a combination of the search for more income and other labor that is not agriculture”	“Los jóvenes se están yendo y buscando otras cosas que les de más dinero. Es una combinación de la búsqueda de mas ingresos y otra labor que no es la agricultura”

Male *Jala* producer, 70 years old

Nevertheless, during the focus group discussions we discovered that young people are aware of what *Jala* represents for the community. Nineteen of the 23 respondents confirmed that this maize landrace represents the cultural identity and traditions of the Jala community. Additionally, the youth groups were able to identify different ways in which *Jala* is consumed and possible markets for landrace products.

4.2 Phenotypic variation and reduction in production of *Jala*

The risk of losing diverse crop landraces became more evident in the 21st century, and it turned into an important topic for governments and public institutions in the discussion of food security and genetic erosion (Chaudhary et al. 2003, Bellon and Berthaud 2004, San-San-Yi et al. 2008, Negri et al. 2009, Berthaud, et al. 2001). *Jala* is one of the landraces that is at risk of extinction (Hernandez-Guzman 2007, Hernandez-Guzman 2009, Hernandez-Guzman 2015, Hernandez-Guzman et al. 2016, Hernandez-Guzman 2018, Costich 2018, Camacho 2018). Researchers have observed phenotypic variations (e.g., size of the maize ear) and a reduction in the area planted with *Jala*. Table 2 shows the ear sizes reported in different articles and how the current average size of maize ear significantly decreased from 60 cm in 1924 to 29 cm in 2018. Similarly, the area planted with *Jala* decreased by more than half, from about 300 hectares in 1924 to 119 hectares in 2018.

The first researcher who documented these changes was Rice in 2004. She reported that in the beginning of 1900s, the majority of the maize planted in Jala was the landrace *Jala*, and only in the 1950s did Tampiqueño, a variety from the state of Tampico, infringe upon the dominance of *Jala*. For farmers and their families, the introduction of Tampiqueño did not change their traditions substantially, as the two maize varieties shared many characteristics. However, during 1970s, when CONASUPO arrived in the valley, other new varieties were introduced in the fields—substantially reducing the share of *Jala* (Figure 6), and changing the production and consumption patterns of many of the families in the Jala municipality. "In much the same way, genetic analysis using 22 microsatellite (SSR) markers on 24 individuals of a Tampiqueño and a Jala population collected for the genebank in 1988 show no detectable genetic differentiation between the populations" (Rice 2004, 16).

The introduction of these varieties combined with the fact that farmers plant *Jala* in small adjoining plots all over the valley have reduced the genetic diversity of maize in Jala valley. This an example of how changes in policies and in market structures generate genetic, environmental and social transformations. Leclerc and d'Eeckenbrugge (2012) argue that crop diversity is the result of an interaction of genetic, environmental, and social differentiation factors. We use these three factors as a way to explain the reasons why phenotypic variation and area planted to *Jala* has been decreasing. Table 3 presents a summary of the genetic, environmental, and social transformations that have led to changes in the *Jala* phenotype and production.

One of the main reasons why farmers replaced *Jala* variety or reduced their area planted to *Jala,* was due to the lower yield compared with other landraces or varieties. As Smale and Bellon (1999) noted, if farmers are in situations that thwart their own economic interest, such as foregoing yield, they should not be expected to continue cultivating the landrace unless the landrace provides uniquely valuable traits. Often, in fact, they continue to grow the landrace alongside the improved variety. Similarly, Graddy (2013) stated that the implementation of *in situ* conservation presents a paradox. In many areas of the world, there are strong pressures for farmers to adopt a more industrialized, high-input, export-oriented mode of agricultural production or abandon farming altogether (Polanyi 1944, Berry 1978, Patel 2007). As stated above, modern maize varieties or more marketable maize landraces have been introduced to the farming system in the Jala municipality. The proximity of these varieties to the *Jala* led to cross pollination and increased genetic flow, "contamination" by alleles from new varieties in the valley, affecting the genetic variability of the seeds conserved *in situ*.

Likewise farmers have been motivated to substitute *Jala* with other crops, such as tobacco (*Nicotiana tabacum*) and other alternative, cash crops such as sugarcane (*Saccharum officinarium*), sorghum, pasture, and peanut (*Arachis hypogaea*) (Rice 2004).

"Now what is harming us is the sugarcane plague. They are given good resources: seed to sow for 5 years."	“Ahora nos está perjudicando la cuestión de la plaga de la caña, la caña dulce que se las llevan a Tepic. Allí les dan un buen recurso donde les dan semilla para sembrar y todavía les queda cuando ya cosechan y son 5 años”

Male *Jala* producer, 52 years old

Further, changes in Jala’s population and urbanization of the cities have shifted land from agricultural to other economic uses. Different types of infrastructure have been constructed, such as roads, highways, educational centers, greenhouses and galleys for the drying of tobacco. These social changes generate environmental impacts in the Jala valley, such as drainage of the phreatic mantle, which reduces the soil that conserves residual moisture, soil depletion, and changes in the microclimate. These transformations, in turn, affect the essential conditions needed for the *Jala* cultivation. *Jala* needs a special combination of environmental and agronomic factors to reach its maximum growth potential (A. Hernández-Guzmán 2018). The plant needs fertile soil, abundant humidity, and relative high temperature and the Jala valley is one of the unique places that has all factors combined (Wellhausen and Roberts 1951). However, climate change, urbanization, poor soil management and the abuse of chemical inputs are reducing the favorable conditions that allowed *Jala* to realize its full potential.

An additional social challenge is the intergenerational change which is contributing to the reduction of labor force in the agricultural sector and the number of Jala producers. Young people are migrating either out of the municipality or to other economic sectors and current *Jala* producers are growing older. Often, younger generations in farming families express little interest in continuing the family business. As a follow up on Rice (2004), CIMMYT’s researchers went back to Jala on 2017 to interview the same 79 *Jala* producers covered in 2001. Figure 7 shows the results from the exploratory exercise. Sample attrition reflects this intergenerational problem. About 30% of farmers originally interviewed in 2001 are no longer cultivating Jala variety and another 34% have died and their descendants are not planting *Jala* variety.

Lastly, the suboptimal selection of *Jala* seeds is affected by both social and environmental transformations. This hypothesis is related to the largest ear of corn in the world contest, that is celebrated every year in Jala on August 15th. During the contest, farmers that produce *Jala* bring their three longest maize ears and compete to see which one has the largest ear. At this time of the year, however, the ears are young and tender, ready to be eaten boiled or grilled but too humid to be conserved for seeds. It seems that farmers have been selecting the longest and healthiest ears of corn for the contests, instead of storing them as seeds for future production (Zabala 2018). Without a conservation strategy, farmers have been doing a "negative selection" of *Jala* with shorter ears and plants and other undesirable characteristics that represent the *Jala* that they are planting today.

4.3 *Jala* rematriation project: protecting traditional landraces

Protecting traditional landraces is of great importance. Promoting complementarity between *ex situ* and *in situ* conservation models represent an efficient approach to achieve this goal. The *Jala* rematriation project by CIMMYT is a representation of the *circular model* presented by Berthaud (1997). As shown in Figure 8, the combination of *in situ* and *ex situ* conservation methods with utilization activities, such as evaluation, generates a cycle of germplasm exchange were both utilization and conservation are happening. This figure is based on the model created by Bellon, Pham and Jackson (1996), and represents the exchange of different types of germplasm among the conservation and utilization activities. This whole cycle depicts the rematriation process that CIMMYT together with other stakeholders are proposing.

As the model is circular there is no a particular starting point. However, for the sake of this report we will start from the *ex situ* conservation method. Landraces, in this specific case – the *Jala*, accessions collected many years ago are brought to Jala fields and planted with the help of farmers, depicted in Figure 8 as (1). In this particular project, researchers selected a pilot plot to test the vigor of the *Jala* accessions kept *ex situ* in the CIMMYT genebank and to document the phenotype of these accessions. This methodology can be complemented with the use of molecular and biochemical markers to have greater precision (Sánchez et al. 2000, Vigouroux et al. 2008).

At the same time, *Jala* seeds that have been *in situ,* conserved traditionally by local communities, were collected and regenerated in order to expand the genetic base of this landrace, depicted in Figure 8 as (2). On average, the collected cobs were 29 cm long and were collected from different localities all located in the Jala municipality: Jala town, Coapan, Jomulco and Cofradía de Juanacatlán (see Table 4). From these 28 donors, 269 maize ears were collected, each one representing an individual accession. A balanced compound (or bulk) was formed from this collection and subjected to recombination in an isolated lot. The objective of this step is to regenerate the *in situ* and *ex situ* conserved seeds in a plot located in the Jala municipality.

Once the plants started growing, scientists conducted a phenotypic analysis and compared differences in expression among the plants. To carry out this step, the team from CIMMYT used a plot in the plateau, in the town of Cofradía de Juanacatlán (see Figure 9), where they planted the donors' seeds, the *ex situ* conserved seeds and the bulk in separate spaces to avoid cross pollination. As the analysis still ongoing we will use the results from Montes-Hernandez and colleagues who conducted a pilot project using a share of the Jala producers' seeds in 2014. They found little phenotypic divergence between the majority of the current populations of the *Jala* landrace conserved and characterized *in situ*, which presupposes a reduced and common genetic base (Montes-Hernandez et al. 2014). Plant height, ear height, and length of the cob were the most important morphological criteria explaining the phenotypic variation in the germplasm evaluated.

While the previous point connects *in situ* conservation with evaluation and the utilization of the plant genetic material by scientists, the Jala rematriation project also promotes and empowers farmers to conduct participatory breeding. Rematriation aims 1) to promote collaboration and exchange of genetic material among peer farmers and 2) to encourage the transfer of knowledge between the formal and informal innovation systems. The former is happening already to some extent with the current seed exchange systems. However, the seed selection process has been poorly managed, as can be perceived from the undesirable phenotypic changes that have occurred, which implies that farmers might be lacking updated knowledge and tools. Consequently, the Jala rematriation project will provide farmers with additional tools that can be combined with their experience to manage their farm more efficiently and to motivate them to conserve landraces that also fulfil their preferences as producers and consumers. The training and knowledge transfer process will be implemented through workshops, where discussions with scientist and peers will be promoted, as well as spaces where farmers can work directly with breeders. By promoting the dual knowledge exchange, this circular model can be more sustainable in the long run.

Finally, the main concern of farmers is the lack of market demand for *Jala* variety. Therefore, to sustain the rematriation cycle, it is very important to take into consideration the market preferences driven by consumers, in Figure 8 (3). Through the Jala rematriation project, CIMMYT will 1) implement a market and value chain analysis in order to identify potential market opportunities for *Jala*, documenting flaws and inefficiencies, and assessing producer and consumer preferences, and 2) help farmers to identify niche markets that are interested in the uniqueness of the *Jala* and are interested in paying premium prices.

Seed rematriation is an initiative by which genebanks can generate a positive impact on rural communities not only by fostering dynamic conservation strategies but by encouraging the exchange of ideas and knowledge between the different germplasm users and stakeholders. In addition, the promotion of knowledge exchange between the different actors through seed rematriation might result in the creation of an intellectual soup (Smith, Copley Sr and Jackson 2018). As proposed by Smith, Copley Sr and Jackson (2018), an intellectual soup arises from a reformulation of two intellectual tradition and bodies of knowledge. A seed (or germplasm) is a living element that embeds scientific, technical and traditional knowledge. The rematriation of such elements involves a combination of traditional and scientific knowledge combined with a cultural heritage. The reconfigured knowledge embodied by the seed or germplasm is the one that is being rematriated to their original communities from which they should maintain a dynamic exchange of ideas. Finally, for biodiversity conservation to succeed among rural farmers, the process must be linked to rural development efforts that give equal importance to local resource conservation, food self- sufficiency, and links to the market (Koohafkan and Altieri 2011).

5. Conclusion

The importance of conserving landraces is undeniable, and they represent an important part of the genebank collection. However, *in situ* conservation is also needed. Landraces have been bred and produced by farmers (and their communities) over centuries, hence they are intertwined with their culture and traditions and adapted to their specific microclimate.

In order not to lose that adaptability to environmental conditions and the connection the community has with traditional varieties, a circular and dynamic conservation strategy is needed—where *in situ* and *ex situ* conservation methods are complementary. The dynamic conservation model focuses on ensuring safe and long-term conservation of landraces, by combining *ex situ* and *in situ* methods. This model focuses not only on protecting genetic integrity of the landrace but also the social and economic utility of the landrace, by creating nurturing environment is co-created to utilize the landraces for inclusive and sustainable agriculture and led economic growth. The model also promotes knowledge exchange between different stakeholders with different genders and ages, and enhances to enhance the cooperation between different users and stakeholders, considering the traditional knowledge and cultural heritage that is embedded in these landraces

The CIMMYT genebank has been instrumental in the project to rematriate *Jala*. The genebank is keen to return the seeds from *Jala* that have been conserved for more than sixty years using the *ex situ* conservation method to its place of origin. Yet, the goal is not just to return the seeds, but also to build a circular and dynamic conservation strategy where the landrace is secure from sudden and extreme environmental risks not encountered in *ex situ* conservation and farmers can also retain a part of their culture. The CIMMYT genebank intends to build a more integrative, collaborative, and respectful partnership with producers and at the same time, promote *in situ* conservation among farmers.

With the introduction of the concept of rematriation and the circular model of dynamic conservation, the genebank at CIMMYT is leading a unique initiative. CIMMYT is supporting a more sustainable method for farmers to conserve and utilize diverse set of maize varieties, contributing to increased farmers' access, control, and access to crop genetic resources and reduced genetic erosion of valuable landraces of maize.

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List of tables

Table 1. List of resource scientists interviewed

Name	Position	Affiliation
Dr. Denise Costich	CIMMYT maize genebank manager	CIMMYT Maize genetic resources program
Dr. Carolina Camacho	Associate Scientist - Social Science	CIMMYT Socio-economic department
Cristian Zabala	Assistant research associate	CIMMYT Maize genetic resources program
Dagoberto Flores	Retired worker and consultant	CIMMYT
Gilberto Gonsalez	Consultant and retired university professor	CIMMYT
Dr. Víctor A. Vidal Martínez	Coordinator	INIFAP, Nayarit
Arhaón Herandez	Professor and researcher	Colegio Post-graduados campus Puebla
Dr. Terrance Molnar	Maize Breeder	CIMMYT

Table 2. Changes in the size of the Jala maize's ear and are planted.

Author (publication year)	Average length of Jala maize ear (cm)	Area planted (ha)
Kempton (1924)	60	324 to 283
Wellhausen and Roberts (1951)	45 to 50	Not reported
Aguilar et al. (2006) and Rice (2006)	35 or 40	366
Montes-Hernández, et al. (2014)	35-44	Not reported
Today (2018)	29	119

Table 3. Possible reasons for the decrease in phenotypic variation and area planted to Jala maize.

	GENETICS	ENVIRONMENTAL	SOCIAL
1	Potential loss of alleles Increased genetic flow, "contamination" by new alleles from new varieties in the valley	Use of different agricultural inputs. Sometimes increasing the use of chemicals cause reduction of the phreatic mantle, the soil layer that conserves residual moisture	Replacement of traditional maize land races (e.g. Jala) by modern varieties or other crops
2	Reduction of area planted with Jala reduces size of genetic populations	Changes in the microclimate and soil depletion	Changes in the land use due to modernization and urbanization of cities
3			Decreased interest from farmers to plant Jala maize
4	Suboptimal selection of Jala maize specimens		Jala maize not meeting consumers and farmers preferences

Source: author

Table 4. Donors of Jala maize seed.

DONOR ID	TOWN	# OF COBBS	COBB LENGTH CM	GRAIN COLOR	# OF SEEDS	INTEVIEWED	AGE (2018)
1	Coapan	11	30	Cream	11	Yes	
2	Jala	9	24,5	Yellow	9	No	
3	Jala	20	31	Cream	20	No	65
4	Coapan	23	24	Cream	23	No	
5	Jala	17	28	Yellow	17	No	
6	Jala	18	30	Cream	18	Yes	75
7	La Cofradia	21	27	Cream	21	No	
8	Jala	18	28	Cream	18	Yes	64
9	Jala	5	29	Cream	5	No	
10	Huascada	4	25	Yellow	4	Yes	70
11	Jala	4	33	Yellow	4	No	52
12	Jala	4	28	White	4	Yes	75
13	Copán	3	28,5	Yellow	3	No	
14	La Cofradía	4	25	Cream	4	No	
15	La Cofradía	4	30,5	Cream	4	No	
16	La Cofradía	3	29	Yellow	3	No	
17	La Cofradía	4	30	Yellow	4	No	
18	La Cofradía	10	29	Yellow	10	No	
19	La Cofradía	4	29	Yellow	4	No	
20	La Cofradía	14	31	Cream	14	No	
21	La Cofradía	12	29,5	White	12	No	
22	La Cofradía	12	30	Yellow	12	No	
23	La Cofradía	8	26	Yellow	8	No	
24	La Cofradía	6	28	White	6	No	
25	La Cofradía	6	26,5	White	6	No	
26	La Cofradía	5	26,5	White	5	No	
27	Jala	4	29	Yellow	5	Yes	
28	Jala	16	35	Cream	16	Yes	52
29			Not donor			Yes	41

Source: CIMMYT

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Figure 1. Location of Jala, Nayarit. Source: (Rice 2004)

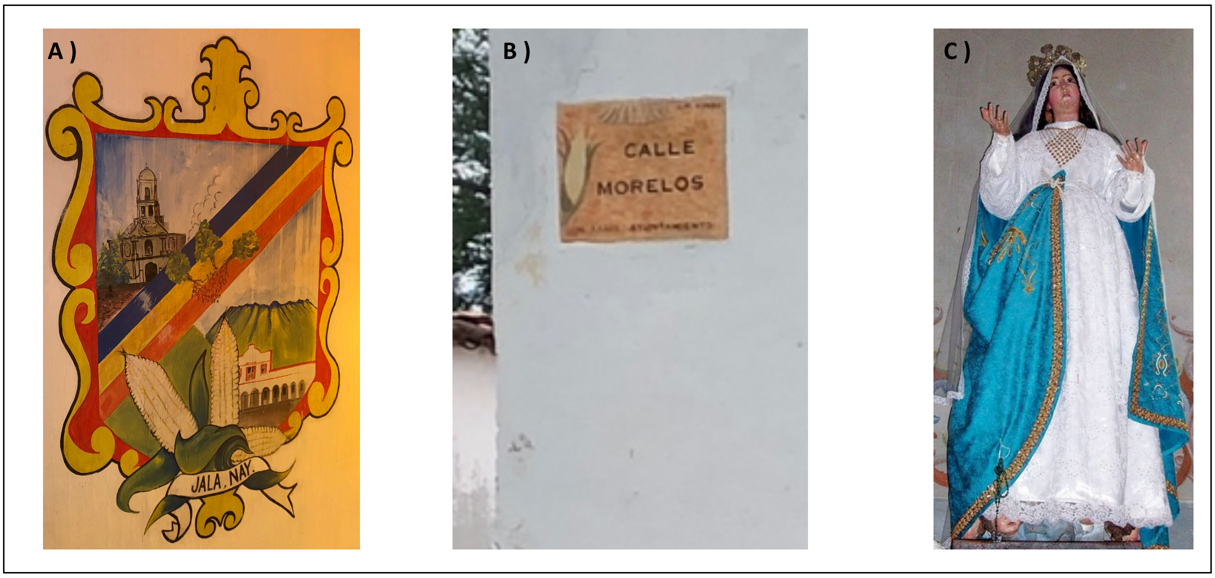

Figure 2. Jala maize in daily items. Source: author

Figure 3. Sanctuary of the Assumption Virgin. Source: author. Notes: Location: town of Jala the house from a male producer, 50 years old

Figure 4. Winner of the Largest Ear in the World Contest. Source: author. Notes: From left to right: one of the contests judges, winner of the contest and father of the winner, both Jala maize producer.

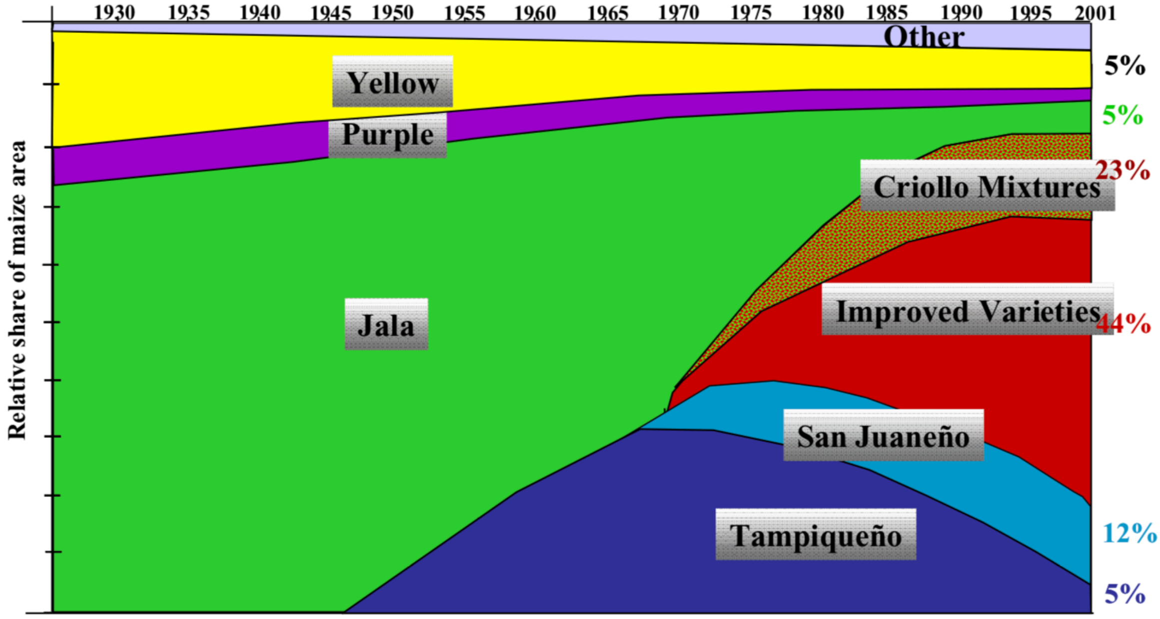

Figure 5. Reconstructed maize areas planted in Jala, from 1925 to 2001. Source: (Rice 2004, 16)

Notes: †The figure is based on 36 informal interviews from 1999 and a formal survey of 79 households in 2001. The reconstruction is intended only to illustrate gross proportions of area cultivated and is only as accurate as the recollections of the interviewees

‡Colored percentages on the right side of the figure reflect actual proportions of each variety found in 2001 random survey of 79 households.

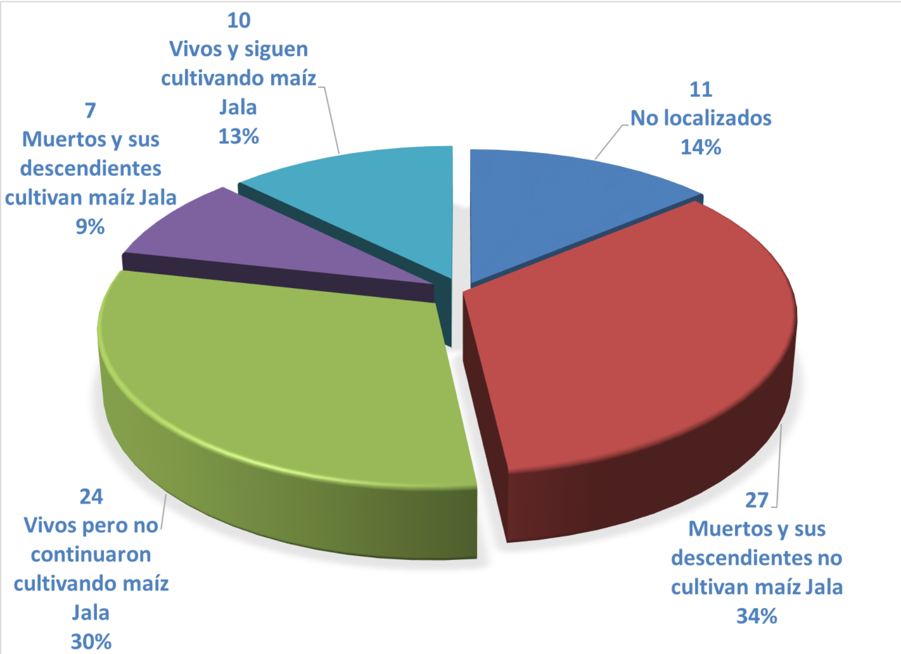

Figure 6. What are the Jala maize farmers doing after 10 years? Source: (Camacho 2017)

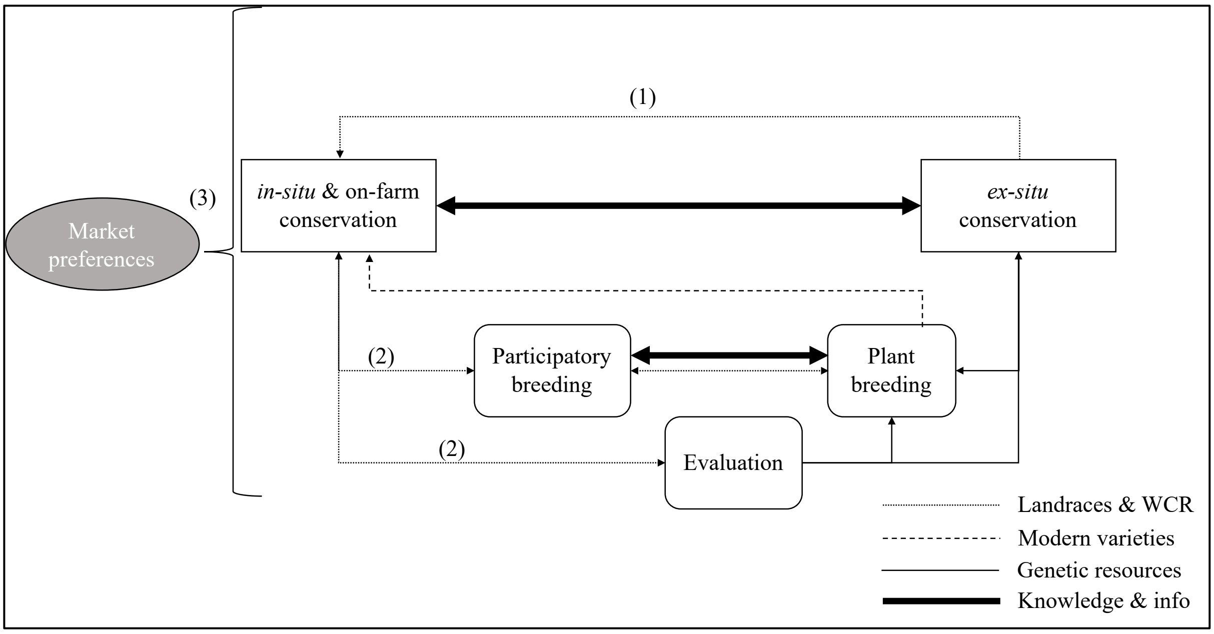

Figure 7. Possible exchanges of genetic material between the different utilization and conservation activities. Source: author based on (Bellon, Pham and Jackson 1996)

Figure 8. Visit to the rematriation plot in Cofradía de Juanacatlán. Source: Author