TARO AND FOOD SECURITY IN SENEGAL

A Project Paper

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by

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ABSTRACT

Taro, Colocasia esculenta (L.) is a tropical root crop that functions as an important subsistence staple for various communities around the world. Many factors have contributed to taro becoming an orphan crop, including agricultural modernization, export-centric crash crop systems, and colonial agricultural administrative policies. The emergence of maize and rice, coupled with the emphasis on groundnut production as a cash crop has replaced the traditional importance of taro in Senegal. Taro is a unique buffer against starvation for rural farmers especially during times of drought. Its corms can be stored in the ground for months – acting as nature's refrigerator since they can be uprooted when needed. All parts of plant are edible and do not only have to be grown for their bulbous roots but can be grown for their young leaves which act as a tropical spinach providing much-needed vitamins and minerals. Micronutrient deficiency is pervasive in Senegal and is largely due to cropping systems that are based on just a few cereals. The potential of taro in Senegal could increase the nutrition and food security for many rural communities. Currently, very little is known about taro in Senegal. It is postulated to be one of the major subsistence staples in West Africa before the Transatlantic Slave Trade. This research paper focuses on an extension project that re-introduced taro to 15 farmers in 2015. A Follow-Up research trip in 2017 was conducted with the same farmers to understand the benefits associated with cultivating taro and the barriers preventing farmers from adopting it. Based on the findings, recommendations are developed to offer solutions on how taro can be utilized to achieve crop diversification and food security in Senegal

Keywords: *Ethnobotany*, *Food Security, Orphan Crops, Senegal, West Africadsfs*

BIOGRAPHICAL SKETCH

Naadhira Ali is a research specialist who has a history of building collations in various communities locally and internationally. She has been dedicated to service work for much of her professional career, first working on sanitation projects in South Asia in the mid – 2000s, then later onto food justice initiatives as an undergraduate in Honolulu, Hawaii.

From 2013-2015,she lived in Kaffrine, Senegal as a Peace Corps Volunteer. Her projects focused on restorative, conservation, and sustainable agriculture. One of her major projects consisted of extending taro root as an alternative rainy season crop in Kaffrine. She trained farmers in crop diversification and monitored dry-land taro fields. Naadhira managed a series of technical training that focused on the overlapping importance between nutrition, health, and diverse agricultural systems. She helped create community mapping and capacity building workshops with local leaders to identify underutilized resources.

After her time in Senegal, Naadhira worked in the Eastern Region of Ghana with a team of university students to conduct research on farmer preferences and the ethnobotanical importance of taro root in crop diversification. Naadhira completed various grants including the agricultural assistance grant from USAID Feed the Future fund which enabled female farmers from a Women's Group access to four hectares of their own farm land.

At Cornell, she worked on the System of Rice Intensification project. She also worked at the Conservation Agriculture project, which was an agriculture database that makes research resources accessible to university students in Africa, Asia and Central/South America.

As a graduate student she focus on Tropical Agriculture and was a Foreign Language Area Studies Fellow for South Asia Studies & Hindi

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1. Introduction

Underutilized crops are largely unseen in markets around the world. They are plants species commonly grown for subsistence and are tucked away in the cropping systems of small communities that depend on their nutritional benefits to live day-to-day. These crops are characterized often by being traditionally grown in closed loop systems, close to their center of origin. Many underutilized crops have been domesticated by generations of farmers that adapted them to grow in local conditions. Neglected crops were not always unknown - in fact, there are many factors, which have caused crops like taro to become underutilized. The dynamics that have pushed these crops to become marginally consumed around the world include the emergence of agricultural modernization, export-centric crash crop systems, and colonial agricultural administrative policies (Padulosi et al., 2013).

Agricultural research concentrates its efforts on increasing the yields of major commodity crops (Tadele & Assefa, 2012). While Indigenous crops have the potential to act as alternative energy sources and improve nutrition. These crops can also help achieve food security in areas where climatic conditions like drought are common. Currently, the global food supply relies on an estimated 30 plant species to nourish 95% of the world (Jain & Gupta, 2013). Crop diversification is not only important on a nutritional level, but also contributes to increase biodiversity on a global level. Cultivating crops that are only economically viable puts farmers and communities at a higher risk of hunger and poverty. Although many smallholder farmers produce food for household consumption, they tend to sell any surplus to markets to generate additional income. Farmers commonly choose crops like maize, that are economically valuable, but not the most climate-smart or

nutritious (Global Forum on Agricultural Research, 2005). Underutilized crops are often called "orphan crops" – a term that illustrates their forgotten importance as vital food sources. The underutilization of orphan crops has only worsened with consumption shift towards maize and rice, which by contrast, are exported on the global market (Padulosi et al., 2013).

This research paper explores the potential of taro root (*Colocasia esculenta*) to enhance food security in areas where it is suitable to grow as a complementary, alternative crop. The focus of this research is to analyze the potential of taro to assist in achieving food security, improving nutrition, and increasing rural livelihoods. Through farmer-centric research, taro root was introduced to 15 farmers in the Kaffrine region of central Senegal. This paper investigates the benefits associated with the re-introduction of taro and the barriers preventing farmers from adopting it. In addition, it catalogs the factors needed to encourage farmers to grow underutilized crops. There is currently very limited research on taro cultivation in Senegal. This research paper examines the historical prevalence of taro in Senegal by using indigenous ways of knowing as an approach to shed light on the people and communities that have been historically growing taro in Senegal (Padulosi et al., 2013).

The author is a returned Peace Corps agriculture volunteer who lived in Senegal between 2013 - 2015, she worked with farmers to improve their agricultural practices and support them with resources such as grant applications for funding sustainable agriculture projects in the Kaffrine region. As a volunteer, she spent much of her time in Guennte gouye, a small community in Kaffrine that has limited infrastructure connecting it to

other parts of the region; a partial laterite road served as the only path for commuting out of the community.

She participated in the agricultural Seed Extension program with ISRA (Senegal Institute of Agricultural Research) and extended improved varieties of rice, millet, sorghum, cowpeas, and maize to farmers in Kaffrine. The project was a collaborative partnership between the Peace Corps and USAID's Feed the Future program. The program's aim was to improve the livelihoods of farmers in locations where Peace Corps Volunteers serve.

When harvest is not enough to last throughout the year, it is common for farmers to use their income to purchase broken rice to feed their families when crops fail due to unpredictable rains, low performing seeds, or poor harvest. In response to the challenges and cycles of poverty smallholder farmers face year-to-year, the author traveled to southern Senegal to understand traditional agricultural practices. In southern Senegal, many minority ethnic groups in Kédougou still utilize orphan crops to prevent food insecurity. For example, the Jahanke[1] in Kédougou use a wide variety of crops such as fonio (*Digitaria exilis*), sorghum, and taro. These neglected crops are pounded into porridges and stews. Although fonio and taro are missing from urban markets in Kédougou, Jahanke farmers are never hungry because they cultivated an array of crops.

Taro is regarded as a high value staple in the traditional Hawaiian food system. Not only did taro feed the population of the Hawaiian in ancient times, but was also revered as a spiritual crop that brought people closer to their ancestor *Wakea* – the first Hawaiian who was considered to be a still born in the form of taro. It was this cultural

[1] Jahanke is a minority ethnic group that resides around the Senegambia and southwest of Kédougou Region (Sanneh, 1981).

and ethnobotanical importance of taro in Hawaii that propelled the author to take up this research and link the patterns of indigenous ways of "knowing" regarding taro. Outside of the Pacific and Asia, little is known about taro.

The project entitled "Crop Diversification with Taro root" provided over 50 kilos of taro corms cuttings from farmers in Kédougou that had been growing taro for generations in Senegal to extend to farmers in Kaffrine. The Crop Diversification with Taro project re-introduced taro to farmers in the Kaffrine region of Senegal and was launched in the rainy season of 2015. A total of 15 farmers participated in the research. One of the objectives for this paper was to understand how taro can be used as an alternative field crop when other crops fail. The project also sought to understand how taro and other underutilized crops could be mobilized to achieve food security in rural communities that depend on subsistence agriculture.

In 2017, with support of the Richard Bradfield Research Award, the author returned to Kaffrine during the rainy season to follow up with the same farmers that participated in the 2015 study. The 2017 research follow-up consisted of field visits and farmer interviews from the same farmers that participated in the Crop Diversification with Taro project. During the follow up visit, farmers' detailed the factors that led to their adoption or dis-adoption of taro root An ethnobotanical background of the traditional ways taro has been cultivated in Senegal was undertaken to support future institutional efforts to explore the opportunities taro has to offer.

This research paper takes an in-depth approach to analyze the obstacles affecting the adoption and utilization of taro root in Senegal. The importance of a re-introduction program of taro root is important because it has lost its value in contemporary agricultural

systems in Senegal. This study will provide an applied understanding taken directly from the field of smallholder farmers in Senegal to understand the key factors which influence their decision to adopt or dis-adopt taro as an alternative field crop to achieve crop diversification. The term 'adopt' refers to farmers that have incorporated taro into their cropping system. The word 'dis-adopt' refers to farmers that decided to discontinue cultivating taro after the 2015 Crop Diversification with Taro project.

Objectives:

The main objective of this research was to evaluate and recognize the factors that influence the adoption or dis-adoption of taro root by farmers as an alternative rainy season field crop in the Kaffrine region of Senegal. The following are topics covered in this paper.

- A literature review to compare what other researchers have said about taro, documenting the nutritional and botanical importance of the crop.
- Summary of the project and findings from the 2015 "Crop Diversification with Taro Seed Extension," in addition to presenting the findings from the follow-up field visit and research completed in 2017.
- Suggest recommendations for re-introducing taro and other underutilized crops to complement food security in Senegal.

2. Literature Review

Taro (*Colocasia esculenta*) has many names and depending on your location in the world it may be called *kalo*, *imo*, *ioth*, *mal*,*malanga*, *binata, tania*, *tanier*, *tanyah*,*suni*, *sawa*, *jibabwãi*, *kolkas*, *bisupsal*, *dasheen*, *woot*, *eddo*, *elephant ear*, *callaloo*, *cocoyam*, or *jaabahre*. These common, yet alternative names for taro indicate its thriving diversity worldwide. It is estimated that more than 200 different cultivars of taro exist (USDA, 2013). Taro is a wild crop that has been domesticated in many cropping systems and its ethnobotanical importance varies by culture. The significance of the crop can be seen in its botanical classification and pervasiveness as a wild species in numerous tropical environments. Taro is a monocotyledon and derives many key attributes of its classification from this group, including vegetative propagation (Purseglove, 1972). Within the structural grouping of the monocots, taro is categorized in the Araceae family. An estimated 95% of plants in the Araceae family exist only in tropical environments (Boyce, 1995). Taro itself is categorized as a pan-tropical crop, which emerged first as a weed in the wild and has been domesticated by farmers in the tropics to be used as a buffer crop against starvation.

The Araceae family is home to many revered popular plants that are often grown primarily for their decorative properties. The Monstera, Philodendron, and the Spathiphyllum are some of the most common houseplants from the Araceae family (Purseglove, 1972). The physiological structural hallmark that Araceae plants share is the heart shaped leaves that emerge laterally from its stem. Araceae also has vegetative qualities to reproduce themselves over many times again (Boyce, 1995). Taro's

importance is most noticeable as an anti-starvation crop and as an essential starch that provides food security to many isolated tropical communities globally. The edibility of taro is an attribute that distinguishes it from other plants in the Araceae family. The number of aroids that have edible rootstocks are extremely low and taro functions as one of the very few edible roots in the Araceae family (Purseglove, 1972).

Taro is the most propagated plant in the Araceae grouping; it also has the highest nutritional and economic value in its family. Some Araceae plants such as *A. titanum* can produce tubers weighing as much as 70 kg (Boyce, 1995). Climatic conditions in which most Araceae plants are grown have the same common environmental needs. Taro and other Araceae plants grow in environments that are damp, rainy, and shaded. They have elongated rhizomes or herbaceous tuberous roots (Purseglove, 1972).

Origin

Rice first appeared as a weed in flooded taro fields and was selected as a crop in its own right to develop into one of the world's most important grains (Coursey, 1983). Taro has been recognized as one of the earliest crops domesticated by humans. It is postulated that taro has existed in the wild for nearly 9,000 years and has been cultivated for nearly 2,000 years (O'Hair et al., 1982). The early domestication of taro further displays its dominance and flexibility to adapt to various ecological settings. The domestication of taro has been proposed to originate from India, and move westward into Myanmar and China, then southward to Indonesia (Chang 1958; de la Pena 1970; Plucknett, de la Pena, and Obrero 1970).

Subsequently it was brought to Melanesia and Polynesia (Trujillo 1967; Yen and Wheeler 1968). It reached the eastern Mediterranean in classical times; Pliny (AD 23-79) recorded it in Egypt. It spread westwards across the Mediterranean and Africa to the Guinea coast many years after that (O'Hair et al.,1982).

Botany

The botanical classification of *Colocasia esulenta* (L). Schott is represented by its chromosomal set (2n=28,42). Taro is commonly confused with other plants that have similar leaflet shapes and edible aroids (Purseglove,1972). Its taxonomical categorization is diverse and varies by climate; taro is most accurately classified when it has been collected and studied, if possible, from living material (Purseglove, 1972). Many researchers have considered C. *esulenta* as one species, while many others have recognized two botanical varieties, var. *esulenta (*syn. var, typical A.F. Hill) and var. *antiquorum* (Schott) Hubbard & Rehder (Purseglove, 1972).

The shared names for taro have added an additional layer of confusion for the botanical classification of the root crop. In the Pacific, all botanical variations are still referred to as taro. In West Africa *Colocasia* and *Xanthosoma* are both called cocoyam; and in the Caribbean dasheen taro has large central corms with side tubers; eddo has small main tubers, and many side corms (Purseglove, 1972).

The varieties of taro are diverse and different cultivars are most apparent in the color of their leaves and tubers. The tuber color of taro can appear as white, pink, or yellow. The leaves themselves can consist of various shades of green (Purseglove, 1972).

The ecology where taro grows depends on if it cultivated in wetland or dryland systems. Dryland taro will be the focus of this paper since in West Africa most taro is grown under dryland systems. Dryland taro depends on rain-fed agriculture structures. Dryland taro can be grown between 3-9 months of rainfall. It grows best as one of the first crops planted after the rainy season has begun. In Purseglove's *Tropical Crops: Monocotyledons,* it is recommended that at least 2,500 mm is received annually, however, in Senegal taro is grown at lower annual rainfall levels (Purseglove, 1972).

The structure of taro differs as much as its cultivars; on average, it is 1-2 m in height with central corms that develop below ground (Purseglove, 1972). The tubers of taro are typically 15 cm wide and 30 cm long. Leaves are between 20-50 cm long (Figure 2.1). It is rare for taro to flower and even rarer for it to produce seeds (Purseglove, 1972). Taro's root system is fibrous and restricted to the top layers of soil (Onwueme, 1994).

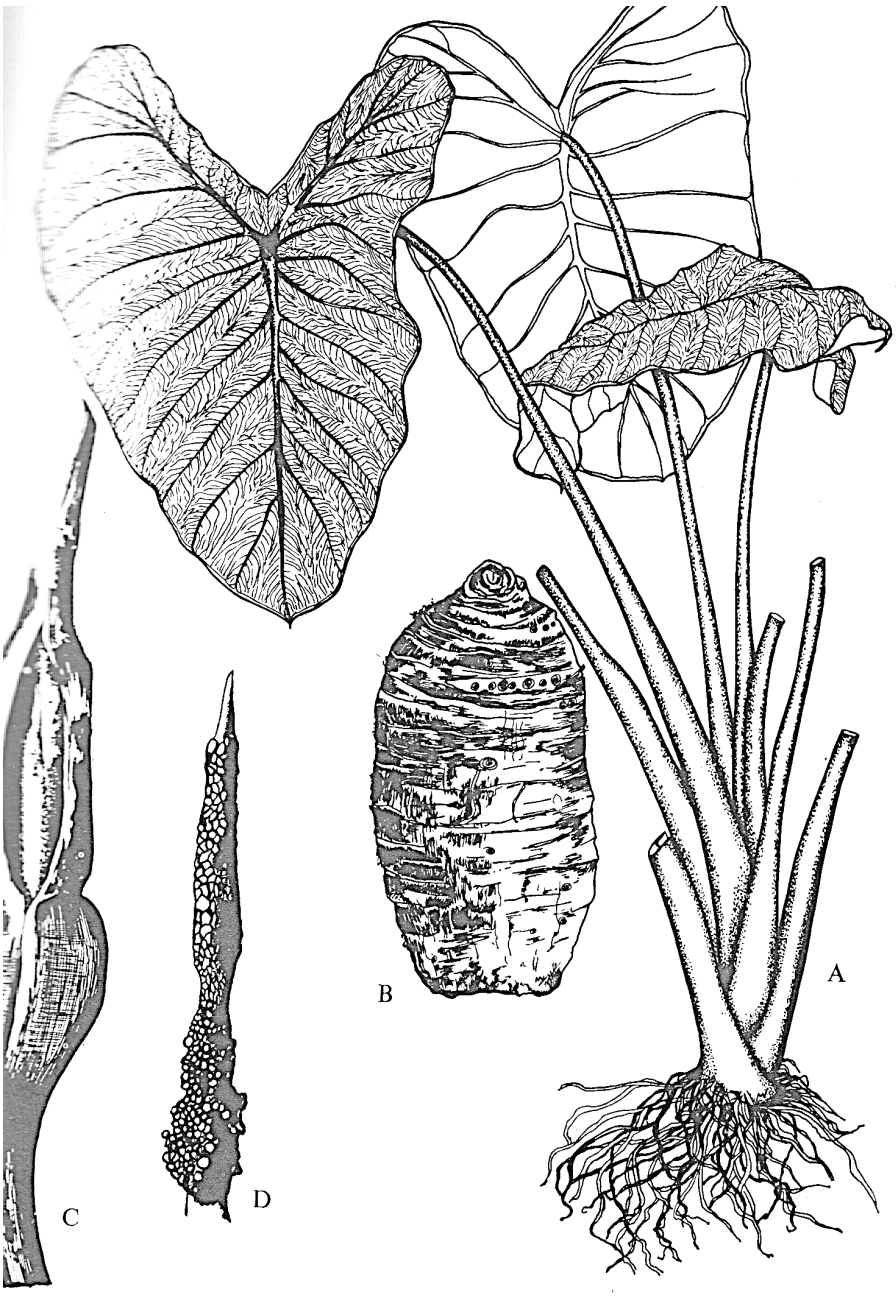

Figure 2.1: *Colocasia esculenta* var, esculenta: Dasheen, Taro. A, young plant; B, corm; C, inflorescence; D, spadix (Purseglove, 1972).

Agronomy

Dryland taro is best cultivated in environments with permeable soil that is not prone to waterlogging or remaining submerged in water for a long period. Taro can be grown on marginal soil, which is uncommon for many other crops. It can also grow well in soils that have high salinity. Land preparation to cultivate the crop starts by digging a shallow pit that is 20 - 25 cm deep. The tuber roots must be covered with loosened soil. In areas with higher elevation, taro can be planted upland and directly in the ground. When soil is deep and porous, the crop can be grown on flat land or ridges. Ridges are usually 70-100 cm apart. Plant spacing on ridges is 50-90 cm (FAO, 1999). Planting in the furrows of the ridges is also commonly practiced. Unlike flooded taro, dryland taro can remain in the field for as long as 18 months before harvest. The most prevalent disease to reduce taro yields is *Phytophthora sp*. Dryland taro must be weeded regularly.

Nutrition

The nutritional makeup of taro can be understood by its chemical composition. Taro's composition is featured and based on Coursey's 1968 documentation of dasheen corms. Taro is 63% - 83 % of water, 1.4% - 3.0% protein; 0.2% - 0.4% fat; 13% - 29% carbohydrate; 0.6%- 1.2% fiber; and 0·6 %- 1·3% ash. Table 2.1 shows the nutritional breakdown of taro raw and cooked. Corms generally are considered a good source of carbohydrates and potassium (Standal, 1970). Standal's, 1970 *Nutritive Value* chapter states an average serving of taro is around 75 g and supplies about 400 mg of potassium. Taro corms become a significant protein source when they are consumed more than once a day. Taro leaves can be used as a tropical spinach and their chemical composition contains 87.2% water; 3.0% protein; 0.8% fat; 6.0 % carbohydrate 1.4 % fiber; 1.6 % ash.

Taro leaves vitamin content includes Vitamins A, B, and C (Standal, 1970) and other research has reported taro leaves as having a generous amount of carotene, potassium, and calcium (Rao et al., 2010). Taro can be eaten like many other dark greens such as mustards or collards. They have been reported to be good sources of phosphorous, iron, and potassium. Taro is a highly digestible crop. The starch granules are small and easily digestible; in fact, an estimated 98.8 % of taro starch has been confirmed to be highly digestible (Langworthy & Deuel 1922; Potgieter 1940). The size of taro starch grain is one-tenth of that of a potato (Payne et al., 1941). People with digestive problems can use it to cure stomach aches. Taro flour has been used as an infant formula especially for children who are sensitive to milk (Rada,1952). In tropical environments, dark greens like spinach, kale, and collards can be difficult to grow. Young taro shoots can be blanched and eaten like asparagus. Callaloo soup, a common dish in Trinidad, is created by boiling the chopped-up taro leaves with okra, ham, and crab. Taro tubers are often prepared boiled, roasted, or baked (Wang, 1970). Corms from wild plants are commonly fed to livestock in Asia.

Table 2.1: Nutrients in Raw and Cooked Tahitian Taro 'Belembe' per 100G (Adapted from Wang, 1970) (Calcium and Potassium data points adopted from Temesgen et al., 2015)

Nutrients in Raw and Cooked Tahitian Taro "Belembe" per 100 G		
Approximate Measure	Raw (10-15 leaves)	Cooked ½ Cup
Kilocalories	36	29
Fat, g	0.9	0.7
Carbohydrate, g	6.2	5.0
Calcium, mg	120	97
Phosphorus, mg	42	34

Iron, mg	1.2	1.0
Vitamin A, IU	2045	4884
Thiamine, mg	0.24	0.20
Niacin, mg	1.0	0.5
Ascorbic acid, mg	96	38
Potassium	2.3 to 4.3 g/100g	N/A
Folates	22 µg	N/A
Vitamin C	4.5 mg	N/A
Riboflavin	0.025 mg	N/A

Taro and Dental Health

Taro has been found to positively impact dental health. During the 1940s, a survey analyzed the tooth decay in a community to compare people who ate only taro and those subsisting on sago (*Metroxylon* sp.) (Kirkpatrick 1935; Potgieter 1940). Those who subsisted on taro had improved dental arches and showed a lower incidence of acute or sub-acute infection of the gums. The dental benefits were attributed to the higher vitamin content of taro. Another study done in Hawaii researched infants' teeth to show how dental health was impacted by taro consumption. Infants that had rice as their main carbohydrate showed higher frequencies of dental decay compared to those of the same ancestry fed a diet where taro replaced rice (Larsen et al, 1934; Potgieter 1940).

Taro in Hawaiian Folklore

Taro's importance in Hawaii is beyond dietary needs; its significance is deeply spiritual, religious, and mythological. In the folk tale of Wakea, taro is believed to be the first-born Hawaiian who was conceived as a stillborn taro, transforming later into human life (Greenwall, 1947).

Taro was moved throughout the Pacific by Polynesians and brought on voyages to other islands (Greenwall,1947). It was first taken to Hawaii by the original Polynesian discoverers around AD 450; later improved varieties developed by Hawaiians were taken from Tahiti about AD 1100, and it played an important part in their civilization, being grown in irrigated plots for the production of poi. The Maori were also said to bring taro with them when they first went to New Zealand (Wang, 1970). Hawaii serves as a center for taro cultivation and conservation. Several varieties of taro exist today; it is estimated that there are 74 varieties in Hawaii currently (College of Tropical Agriculture and Human Resources, 2009)

Taro in Hawaiian Cropping Systems

Taro is predominately consumed in the Pacific, and most notably in Hawaii. In 1778 when Captain Cook arrived, it was estimated that about three hundred thousand people on the islands lived primarily on poi (pounded taro), sweet potato, fish, seaweeds, fruits, and a limited amount of green vegetables (Potgieter, 1940). Food systems are models that encompass all aspects of food production ranging from agronomic practices to consumption. The anthropological influence of food systems is evident in cultural practices and traditions. In Hawaii, the *Ahupua'a* system has been used for centuries as a traditional land management system for food production in Hawaii. Figure 2.2 illustrates this systems structure. The *Ahupua'a* system is defined as an agricultural land division system, extending from the seashore to the mountain ridge (Dorrance, 1993). The *Ahupua'a* structure of ancient Hawaii continues to influence the current cropping system in Hawaii (Figure 2.2). In the *Ahupua'a* system taro is considered a high-value crop.

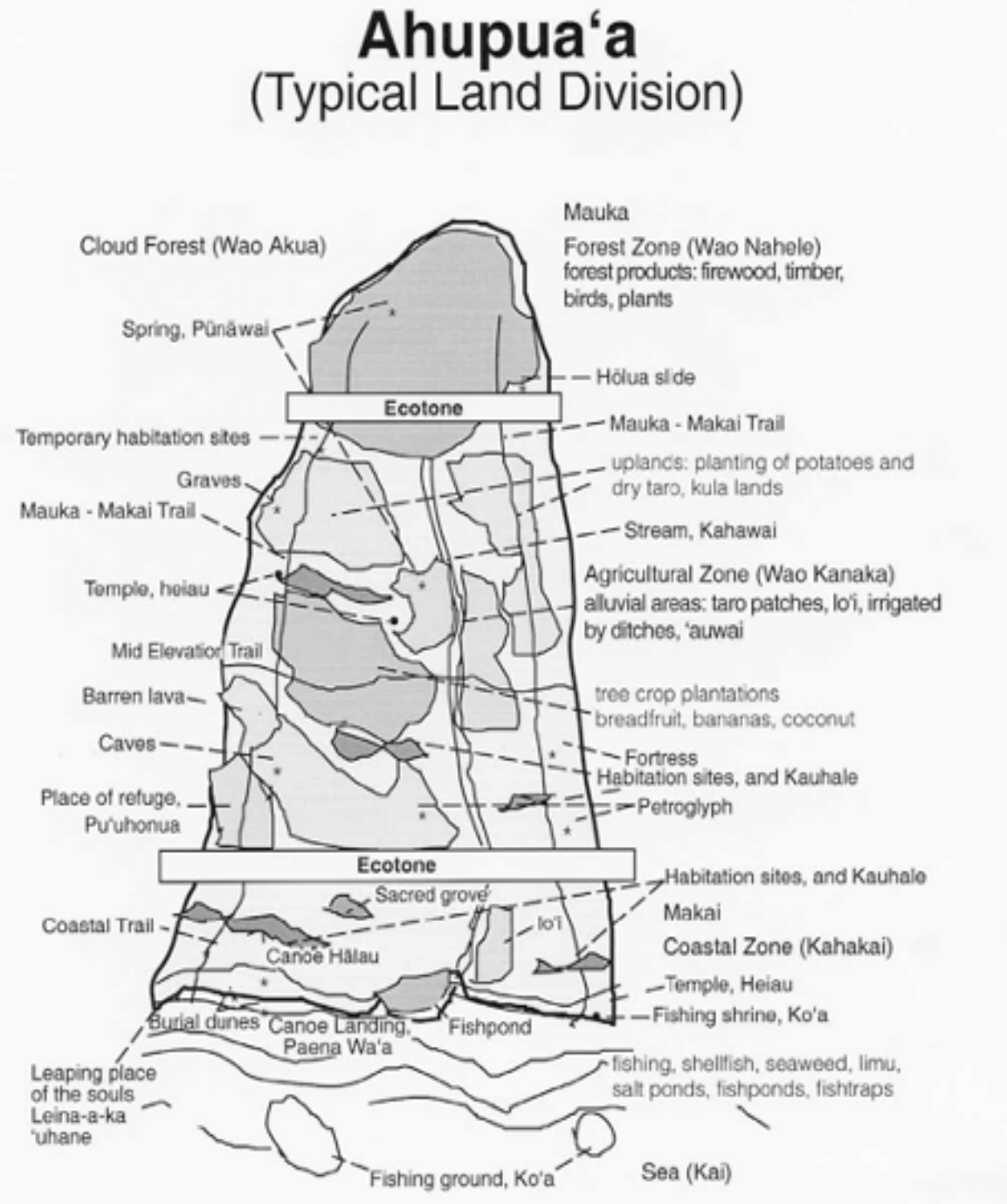

Figure 2.2: *Ahupua'a* model after Luciano Minerbi 1999, slightly modified. Note the five biological resource and production zones from mauka to makai: wao nahele, wao kanaka, kahakai, kai, and the kahawai stream ecosystem (Source: D. Mueller-Dombois, 2007).

Traditional irrigation systems called *auwai(s)* were often constructed to divert mountain top waterways to land (Figure 2.3). These waterways were created mid-mountain to create taro paddies called *loi(s)*. In addition to taro, rice, sweet potato, breadfruit, and banana trees were also cultivated. At the very base of the *Ahupua'a* close to the seashore, traditional fishponds were maintained (Dorrance,1993). Fish and poi (pounded taro) continue to serve as dietary staples to the Hawaiian Islands. In Hawaii, poi is a national dish and is made by pounding boiled peeled corms, which are then fermented anaerobically in water to produce a sticky paste (Wang, 1970). The traditional food system model of ancient Hawaii is important because on the island of Oahu there is an incredible effort to preserve elements of the *Ahupua'a* system, especially since the Hawaiian Islands import 85% of food needs from the continental United States (Leung & Loke, 2008). Food security and agricultural self-sufficiency remains a current challenge for the islands.

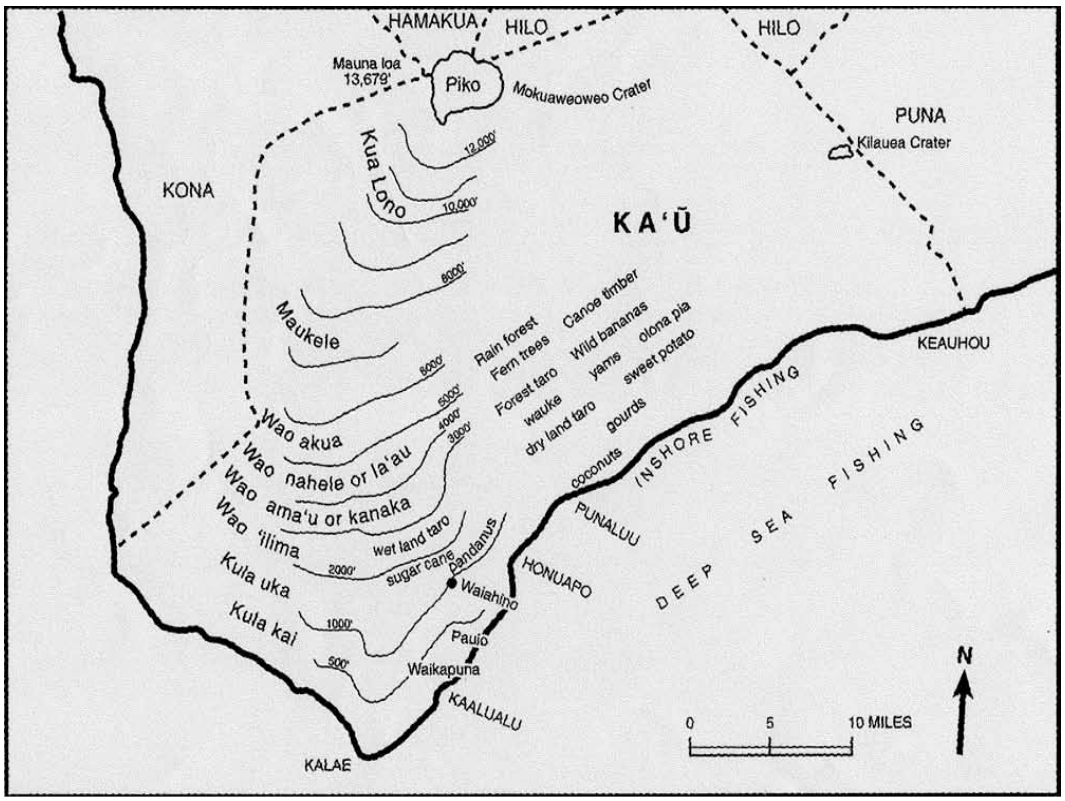

Figure 2.3: The vertical arrangement of Hawaiian ecological zones on the south slope of Mauna Loa, Hawai`i Island [after Handy & Handy (1972) with slight modifications] (By D. Mueller-Dombois, 2007).

Comparison of Taro in the Pacific Production and Constraint in West Africa

Previous research studies have highlighted the potential of taro root to increase food security on the African continent. Ofori, 2001 research examines this potential for increasing production on the continent. By examining West Africa's potential to cultivate and consume taro as a dietary staple, Ofori's research took a comparative analysis on the dependence of cereal crops in Africa. He highlights the challenges taro has as an undervalued crop competing against more economically viable crops within the systems of commodity trade. In addition, Ofori's research provides a model to understand the underlying factors impacting taro's usage as a staple food in the region of West Africa. In researching the potential of taro root, Ofori reviews the historical importance of over

consumption of taro in the Pacific and it's under consumption in Africa. Ofori states "taro is the highest contributor for dietary energy in the Pacific islands, but the largest area of cultivation is in West Africa" (Ofori, 2001). The critical difference between the intensity of taro cultivation in the Pacific and under consumption in West Africa is at the crux of this research paper. Following Ofori's investigation, this paper looks at factors that have led to taro root's marginal consumption in West Africa.

Taro is pan-tropical in its distribution and cultivation, however, its highest contribution to dietary needs occurs in the Pacific. However, the largest area of cultivation is in West Africa, which accounts for the greatest production amount (FAO, 1999). Table 2.2 shows the production of taro around the world by country.

Table 2.2: Production, Yield and Area for Taro/ Tannia in 1998; only the Leading Producers**.** (Adapted from the FAO Database, 1999)

	Production (1,000 tonnes)	**Yield (tonnes/ha)**	**Area (1,000 ha)**
World	6586	6.2	1070
Africa	4452	5.1	876
Asia	1819	12.6	144
China	1387	16.8	82
Japan	255	11.6	22
Philippines	118	3.4	35
Thailand	54	11.0	5
Oceania	283	6.2	46
Papua New Guinea	160	5.2	31
W. Samoa	37	6.2	6
Solomon Islands	28	21.9	1
Tonga	27	6.4	4
Fiji	21	14.7	1

Ethnobotanical Research in Senegal

In West Africa, taro is underutilized. Although the region has the highest area of cultivation, there continues to be a major gap between its production and consumption. This section illustrates information captured in Senegal during research trips to Kédougou between 2014-2017. Many farmers that were interviewed had experience growing taro for generations. Kédougou is a region in southern Senegal that has one of the highest rates of taro farmers in the nation. Kédougou borders Guinea where taro is commonly grown. Figure 2.4 shows a photo of taro grown in this region.

The presence of taro in Senegal is linked to the migration of people from Guinea to Senegal. Taro in both countries is referred to as *jaabahre (JAH-Bah-Rey).* One of the major cultivation hubs of the crop is Labé, a city in Guinea. Labé is often referred to as the center of taro migration from Guinea to Senegal. Guinea is Senegal's more verdant, tropical southeastern neighbor. The pervasiveness of taro in Kédougou, Tambacounda, and Kolda regions of Senegal is directly associated with its proximity to Guinea. The predominance of taro is most emphasized in the southeastern region of Senegal. The spread of Peul Fouta [2] to more interior parts of Senegal such as Kaffrine, Kaolack, and Fatick has increased the presence of taro in Senegal.

[2] Peul Fouta an ethnic minority in southern Senegal. They have traditionally lived semi-nomadic, following the rains from Guinea to Senegal.

Figure 2.4: Taro is grown in a backyard garden during the rainy season of 2017 in the Fouta Djallon (region) (Photo Credit: author).

Taro corms in southern Senegal look red and/or white. The petioles range in colors, and appear from deep purple to pale green. It is cultivated primarily as a backyard, kitchen garden crop and can be seen in small plots that consist of two to four plants. It is rarely cultivated on a large scale of more than half a hectare. People do not grow it as a commercial crop in Senegal. Corms that are sold in markets come from Guinea. Taro is primarily for household consumption and is most commonly used as a snack between lunch and dinner.

In the southern regions of Senegal, boiled taro corms are sold as street food in the evening. Hot chili peppers and salt are condiments that are used to season it. When it is consumed at home in rural villages, it is pounded down into porridge for breakfast. In Dar Salaam locals use the leaves to make a sauce for stew and in this form taro leaves are utilized as a dark green. In West Africa, countries such as Nigeria and Ghana use taro root extensively and it functions as an essential ingredient in national dishes such as

kontomire stew in Ghana and *egusi* soup in Nigeria. The Xanthosoma version of taro is often found across West Africa, and is known for making better *fufu* (Wang, 1970).

The medicinal usage of taro is known to be a cure for people who have stomach issues including bloating, constipation, diarrhea, and pain in the stomach. It is highly digestible and is commonly used as baby food and beneficial to older people without teeth since it does not require chewing. Taro must be boiled for a long time to remove calcium oxalate crystals. These crystals can cause severe irritation to the throat and closes passages for breathing.

Dryland taro is a rain-fed crop in Senegal. The soil requirements to cultivate it are well-drained compost soil. Across Senegal taro is best grown in upland environments or mountainous regions such as the Fouta Djallon, a highland area that borders Senegal and Guinea. In the Fouta Djallon, taro is grown in well-drained soils on hillsides. It is commonly also grown in shady environments under trees or shaded parts of homes. Taro does well when it is planted just before the first rains. It can be cultivated for its corms, which take 3-6 months to develop, or for its nutritious leaves, which take only a few weeks of rainfall to mature.

Common Intercropping and Agroforestry Arrangements with Taro in Senegal

Intercropping with taro root is quite common. Dryland taro unlike wetland taro cropping systems allows taro to be planted with multiple different crops. Intercropping is beneficial and can be used to increase crop diversification. Growth and yield differs slightly between each matrix. For instance, Mabhaudhi & Modi (2014) research entitled "Intercropping Taro and Bambara Groundnut," recommend intercropping taro at a rate of (taro: bambara) 1:2. Taro's plant growth when intercropped with other trees or vegetables remains virtually unchanged. Table 2.3 illustrates the most common intercropping schemes with taro in Senegal. Figure 2.5 shows agroforestry intercropping. Figure 2.6 displays a maize and taro intercropping scheme.

Table 2.3 Common Intercropping and Agroforestry Arrangements with Taro in Senegal

Taro (*Colocasia esculenta)*	Maize (*Zea mays*)
Taro (*Colocasia esculenta)*	Peanuts (*Arachis hypogaea*)
Taro *(Colocasia esculenta)*	Cowpeas (*Vigna unguiculata*)
Taro *(Colocasia esculenta)*	Mango (*Mangifera indica*)
Taro *(Colocasia esculenta)*	Eggplant (*Solanum melongena*)
Taro *(Colocasia esculenta)*	Okra (*Abelmoschus esculentus*)
Taro *(Colocasia esculenta)*	Bambara Groundnut (Vigna subterranea)
Taro *(Colocasia esculenta)*	*Acacia nilotica (Live-fence)*

Figure 2.5 Featured in this photo is a common intercropping system. Mango tree (*Mangifera indica*) provides shade for taro *(Colocasia esculenta)* and maize (*Zea mays*) (Photo Credit: author).

Figure 2.6: Featured in this photo is a common intercropping system with taro and maize (Zea *mays*) (Photo Credit: author).

Senegal, West Africa

Figure 2.7: Map of West Africa (Adapted from Google Maps, 2020)

Senegal is a country that is considered one of the most stable in the region. The Atlantic Ocean is its western coast and extends to Guinea-Bissau making it the most western part of continental Africa. As of 2021, the population is an estimated 15.4 million people with about 42 % living in rural areas (World Bank, 2021). The country has borders with Mauritania, Gambia, Guinea, Mali, and Guinea- Bissau (see Figure 2.7). Senegal has 14 regions, each with an urban capital. The regions include Kaffrine, Kaolack, Tambacounda, Diourbel, Dakar, Thiès, Saint-Louis, Matam, Fatick, Kédougou, Sédhiou, Ziguinchor, Kolda, and Louga. Figure 2.8 is a map of Senegal that shows its regions. Senegal is composed of various ethnic groups, the majority being Wolof, which

comprises 43% of the population. The Fulani are a nomadic pastoralist group that make up 24% of the population. The Diola makeup 5 % of the population and are known for growing *O.glaberrima* rice in Ziguinchor. Serer (15%) live in the Fatick region and are known for their livestock management. Other ethnic groups include the Bassari, Janakane, Soninké (Funk, et al., 2012; FAO, 2015).

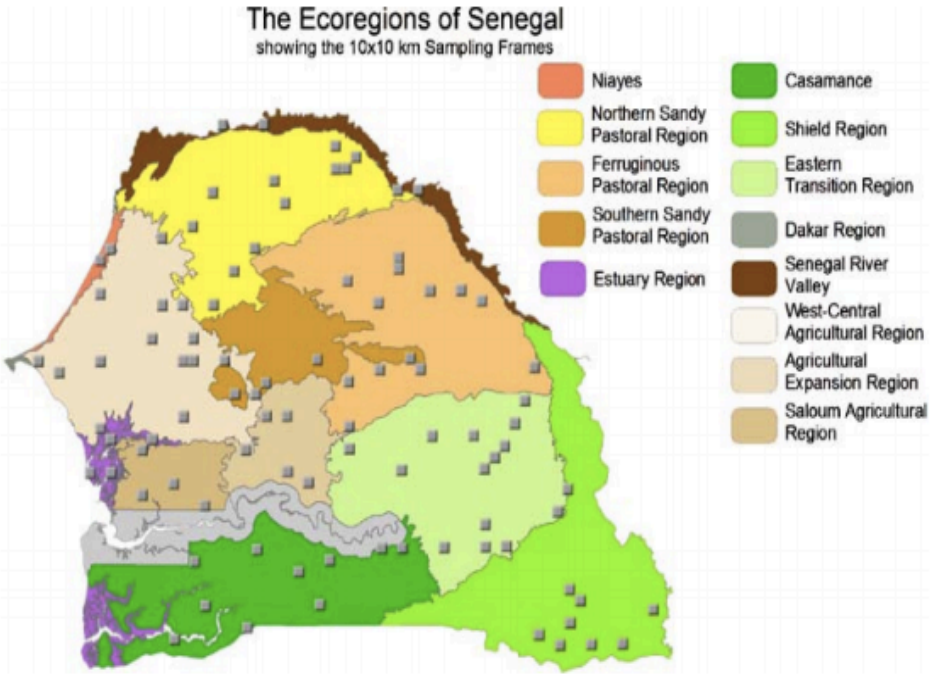

Figure 2.8: Regions of Senegal (Tappan et al., 2004)

Agriculture in Senegal

Agricultural production in Senegal is primarily completed by smallholder farmers that sell their harvest in local markets. More than 80% of the country's vegetables are grown in the Niayes - an area between Dakar and Saint-Louis. Most of Senegal's land is not arable (Tappan et al., 2004). The short rainy season between June and September has made it difficult for farmers to farm all year round. Most farmers depend on wells with

very deep water tables and no electric powered pump making agricultural activities extremely strenuous.

Senegal's agricultural system has many remnants of French colonial agricultural policy, which was heavily focused on exporting groundnuts. Kaffrine is known as the Peanut Basin, and is also known the Saloum Saloum, the traditional empire that occupied the region before contemporary Senegal. Most peanut production for colonial France took place in the Kaolack and Kaffrine region. Other crops grown in the Peanut basin include millet, sorghum, and maize (Tappan et al., 2004). Field crops are rain-fed during the June to September rainy season. In the last 50 years, Senegal has undergone desertification and climate change (Tappan et al., 2004). Factors such as deforestation due to agricultural activities have reduced vegetation. Seasonal drought and high levels of soil salinity are characteristic of Kaffrine. An unpredictable amount of rainfall received each year has made agriculture more difficult for smallholder farmers.

In recent decades, the emergence of maize production has quickly increased across Senegal. This production trend can be seen across the African continent. Maize has surpassed many traditional cereals and grains. Table 2.4 shows the production rates of maize and other cereal crops in Senegal.

Table 2.4: Area and production of selected cereal crops (Adapted from FAO Statistics Division 2015 | 04 October 2015)

Crop	Africa (2012)	
	Area (ha)	Production (t)
Maize	34,075,972	70,076,591
Millet	19,998,008	16,008,838
Rice, paddy	11,206,813	28,798,202
Sorghum	23,142,595	23,350,064
Wheat	10,224,952	24,704,201
Total	**98,226,080**	**162,422,507**

Taro as an Indigenous Crop in Senegal

The exact date of taro's emergence on the continent of Africa is unknown. During the Transatlantic slave trade taro was said to be a starch for enslaved people onboard ships because it was cheap and filled stomachs. Greenwell's writing describes how dasheen was taken in post-Colombian times to the Caribbean during the Transatlantic slave trade (Greenwell, 1947). The utilization of taro continued after enslaved people reached the New World, now the Americas, and the Caribbean fusing the crop into new cuisines.

Factors Contributing to Taro's Status as an Underutilized Crop

Jaw-Kai Wang (1970) states that "the introduction of cash crops have tended to make farmers neglect subsistence gardens and use their money to buy store-bought food" (Wang, 1970). This trend of participating in agricultural work primarily to earn income to purchase processed food introduces serious nutritional problems (Barrau, 1958). An example is the case of Papua New Guinea where research documented dietary standards declining as per capita incomes increased (Wang, 1970). In addition, Jaw-Kai Wang, (1970) discusses the agro-political role of government policies that have further pushed taro to become an orphan crop. Taro production policies by governments are centered on reducing imports and increasing exports. The population's nutritional status in most countries has declined due to a priority on export crops like rice, wheat, and maize. Taro, in particular but also many other root crops have been neglected because they are not easy to export. Taro in turn is only utilized domestically by a small percentage of the population (Coursey & Haynes, 1970).

Bernstein (2010) declares "agrarian communities are dependent on their ability to produce food that is useful for their diets and ecology. When Senegal became a colonial entity controlled by France, its traditional cropping system was forever altered. During colonial control, Senegalese farmers had little to say over the management of their fields. Prior to colonization, Senegalese farmers planted crops that were ecologically appropriate for the Sahel. Under French occupation agriculture was treated as a managerial project and farmers were forced to grow crops for export (Gellar,1978). It is difficult to fully understand the full details of the traditional Senegalese cropping system before the French since much of its historical narrative starts with its colonial occupation. Carney's (2009) historical analysis "*In the Shadows of Slavery",* reminds us of the agricultural intellect of indigenous West African farmers and the cropping systems they created. Although situated at the apex of the Transatlantic slave trade, Carney's historical account of the pre-colonial cropping systems in West Africa provides a framework of how traditional agricultural systems were before French administrative control. We are forced to press for a deeper understanding and question the dynamics of how traditional cropping systems of West Africa have been replaced by low-grade commodity rice imports.

French Modernization of Traditional Senegalese Agricultural Systems

The French agricultural system in Senegal was export-centric and relied on international markets to trade groundnuts cultivated in Senegal. France's administrative control illustrates how colonial, commodity-focused agriculture has altered the nutrition and farming in Senegal, making the population's food security dependent on rice imports.

French colonial agricultural management was viewed as an economic development initiative and the sector itself was a tool to increase income, not nutrition.

Traditional subsistence crops were abandoned and displaced by commodity-driven crops. Senegal's agriculture production by the 1940s was entirely based on groundnut exports (Gellar, 1978), which continues to impact the cropping system today.

Senegal and Other Underutilized Crops Like *Oryza glaberrima*

Rice is an essential part of the Senegalese cuisine and it is used as a major component to many popular dishes; *Yassa*, *Maafe,* and *Domoda* are all rice-based meals. The national dish of Senegal is *Ceebu Jen. Ceebu* translated from Wolof to English means rice whereas *jen* means fish. The emphasis on rice in Senegalese cuisine is manufacture and orchestrated by the introduction of white rice by France. The rice-centric cuisine has played a role in replacing traditional millets and sorghums.

Another explanation that better illustrates the forces that have pushed orphan crops to the periphery in Senegal is when looking at traditional varieties of rice. The reasons why a traditional cultivar of rice would be replaced with an imported form of broken rice with minimal nutritional benefit is the crux for how agricultural economic development initiatives has fostered malnutrition and food insecurity.

Oryza glaberrima is an indigenous dryland rice that is native to Senegal. It is found as a wild plant in southern Senegal. This section will analyze the reasons *Oryza glaberrima* has become an orphan crop. Although different from taro, *Oryza glaberrima* has similar dynamics which has forced it to become an orphan crop. West Africa as a region leads in global imports of *O. sativa* rice from Asia, although it has its own indigenous rice cultivar.

O. glaberrima is a wild plant incorporated into the dryland cropping system through domestication. In the *Ecology of Tropical Food Crops*, Norman (1995), *O. glaberrima* is grown exclusively in West Africa, ranging from Senegal to the Nigerian coast. Another less common rice species that also exists in West Africa, *Oryza barthii,* which is a semi-arid cultivar of rice found across the Sahel, reaching from Senegal to Sudan (Norman, 1995). *O. glaberrima* is a West African rice species that has a high cross-pollination frequency and high seed dormancy. *O. glaberrima* has lower yields than *O. sativa* and is mostly grown as an upland crop. The forces that have pushed taro to become an orphan crop are the same forces that have caused *O. glaberrima* to become underutilized in Senegal. France used global trade networks to import rice from Indochina (Thailand and Vietnam) during periods of drought in southern Senegal (Baum, 1999). *O. glaberrima* existed before and was an important staple crop for ethnic groups in southern Senegal such as the Diola[3] (Baum, 1999). The Diola are an agrarian-based society that revolves around rice production. The Diola were among the most adamant group to resist colonial forces (Baum 1999). A major way the Diola fought against the French was to resist growing crops for export such as groundnuts and *O. sativa* rice. Aline Sitoe Diatta emerged as an important agro-political figure to resist colonial cash crop initiatives. Aline Sitoe Diatta used traditional agriculture as a way to re-assert an early form of food sovereignty. She encouraged the Diola community to continue to grow local cultivars of upland rice (O.*glaberrima*) (Baum, 2016). Colonial agricultural policies restricted the cultivation of upland rice. Although Aline Sitoe Diatta was politically active in the 1940s, French agricultural initiatives to increase groundnut production in the Casamance area began as early as the 1830s (Baum, 2016). The resistance by the Diola

[3] Diola an ethnic that primarily live in the Ziguinchor, southern Senegal.

made peanut cultivation in the Casamance area unsuccessful due to civil unrest. It was only decades later when peanut production began to take off in the Casamance region.

The lower Casamance region of southern Senegal is regarded as one of the first sites of *O.glaberrima* rice domestication. When adequate rainfall is received surpluses of rice are often achieved. In times of seasonal drought and rain variability, rice production is reduced (Baum, 1999). Gender dynamics and social stratification can be seen in the Diola agrarian society. Rice fields were individually owned by men and passed down from father to son lineage lines (Baum, 1999). As peanut production became more lucrative, the male workforce in rice cultivation declined by 50 % (Baum, 1999). Women became the primary source of labor for cultivating rice paddies while men pursued the financial benefits of switching to peanuts. Men exclusively did peanut cultivation. While men increased their earning from peanuts farming the agricultural dominance of women declined. Growing traditional rice varieties became unprofitable and labor-intensive which continued to be done exclusively by women.

Broken rice (riz brisé) is a low-quality rice that was not intended for human consumption but sold as livestock feed. When rice is processed the rice mills produce debris of broken rice - finely fractured broken pieces of rice. A market did not exist to sell the broken rice because the grain had already been broken during milling. Left with an excess of poor quality rice, France found a new market to sell and dump the surplus at a low cost (Davies, 2016). Today broken rice is the main staple in Senegal. People buy broken rice in bulk bags of 25 kilos. The price ranges between 10,000 to 20,000 CFA and serves as one of the largest household expenses. In addition to its price and unpredictable prices, the quality of the broken rice is low and often contains pebbles and dirt mixed in

with the rice. Women who are tasked with preparing all of the household meals spend hours sifting rice between strainers to remove dirt and rocks. After this process, they spend more time soaking and changing the water of the rice before cooking to remove any additional debris. This time consuming practice is done for rice that is processed to the point of being nutritionally void. Figure 2.9 illustrates the racial marketing that goes into selling broken rice in West Africa. Oddly enough, many farmers purchase broken rice despite being from a long lineage of farmers that have grown it.

Figure 2.9: Bongou 25 kg broken rice from Thailand sold in Senegal. (Source: Kosmos Distribution, Pikine, Senegal 2017).

Rice from Indochina was used to substitute for the decline in local rice production in Senegal. It was widely believed by the French that once discharged from the duty of farming subsistence crops Senegalese farmers could free up their farmland to grow groundnuts. With their increased earning, farmers would buy cheaper rice from Asia, which was widely available in local markets and given directly to farmers as a starvation starch in times of crop failure. The decline of locally produced rice resulted in a reduction in area grown of traditional cultivars. Male farmers who own the majority of land in Senegal decided what crops were grown. Many of them converted to peanut cultivation because it brought in more money. As peanuts became the predominant crop, the amount of land dedicated to growing rice was limited. The amount rice grown was minimal and its harvest failed to produce enough rice for the community. Imported rice from Indochina became a staple for the Casamance region although it had traditionally been rice sufficient (Baum, 1999). The prestige of growing an export crop produced class disparity between groundnut farmers and rice farmers in southern Senegal (Baum 1999). As more farmers converted to cropping systems that prioritized groundnuts, the labor force needed to maintain rice production levels dwindled. In the Casamance region, French agricultural officers would extend two sacks of peanuts to local farmers and demanded the loan be paid with a return of four harvested sacks of peanuts (Baum, 2016).

Agriculture policies under the colonial regime actively promoted the distribution of *Oryza sativa* for consumption and cultivation. *O. sativa* was distributed to replace *O. glaberrima* because it produced higher yields (Baum, 1999). The physical differences between *O. sativa* and *O. glaberrima* are significant. *O. sativa* has larger seeds compared

to *O. glaberrima*. Growing *O. sativa* in West Africa posed many ecological issues. It was more susceptible to drought and pest attacks. Although higher yields were possible with *O. sativa,* it could not be grown in dryland systems. *O. glaberrima* was better suited to grow as upland rice, whereas *O. sativa* needed to be planted in well watered conditions. Semi-arid climates are prone to variable rainfall and droughts, this resulted in very poor yields for *O. sativa* in Senegal.

The economic foundation of Senegal's post-colonial agriculture sector revolved around groundnut production. Senegal regained autonomy as an independent state in 1960 from France, however, French colonial agricultural policies continued decades after formal independence. The implications of continuing colonial agricultural policies changed the way agrarian communities in Senegal responded to food supply crises. As the French moved out of Senegal, the Senegalese national government promoted and continued to distribute inputs for groundnuts. It fundamentally continued the agricultural policies of France (Kelly, 1996). The export-based economy of Senegal prepared it for integration into the world economy and World Bank. After independence, a rapid transformation of Senegal's economy occurred which essentially tailored the country to enter the world market (Kelly, 1996). Traditional cereal crops declined since production deficiencies were addressed with rice imports from Asia (Kelly, 1996). Farmers continued to practice the colonial cropping system, which focused on farming export crops not used for household consumption (Kelly, 1996). Minimal support was offered by the national government to help farmers resume growing *O. glaberrima* after it was no longer prohibited. Meanwhile, in Asia, the Green Revolution was underway starting in the mid-1960s. The production of major staples such as wheat, rice, and maize tripled

(Pingali, 2012). There is an association between the surplus of rice production increasing by 157% in Asia and more rice imports to Africa during the same period.

A major component of modernizing agricultural systems was based on the theory of constantly increasing farmers' production of peanuts. The national government provided agricultural inputs to maintain high yields of peanut. The reliance on foreign-based synthetic inputs further made Senegal dependent on expensive imports. In summary, farmers needed inputs to maintain high yields, which created a dependence on agro-inputs such as urea fertilizer – pushing Senegal to rely on the world economy. The 1970s era in Africa was marked by an increase in donors aid to fund agricultural research. CGIARs and other research institutions functioned as the centers of innovation for new technical practices. The World Bank set the stage for integrating Senegal into the global world market. The 1970s – 1980s was characterized by a series of ambitious development projects, many of which came in the form of dams and new irrigation systems (Koopman, 2009). The donor investments that soared in the 1970s were loan-based debts. In the 1980s, the World Bank and other international financial institutions introduced new credit requirements for African governments like Senegal to agree to, as a way to ensure the loans would be repaid. The nature of the World Bank's Structural Adjustment Loan restricted Senegal's government budget and reduced rural farmers' from accessing government subsidy programs (Delgado & Jammeh, 1991). The government responded with agricultural reforms to reduce cost. This drastically removed government subsidies programs for inputs adding more strain on farmers who were now dependent on agrochemical inputs for peanut cultivation. The World Bank's Structural Readjustment Program added more pressure on Senegal to cut back national spending. Now plagued

with billions of dollars worth of debt and dependent on the international community for financial assistance Senegal's economic outlook was bleak.

The implications of structural re-adjustment posed by the World Bank reverberated throughout the local economy. Senegal continued to struggle to secure an adequate rice supply to satisfy national demand. The peanut export industry to Europe no longer exists mostly due to an import ban from Europe of Senegalese peanuts due to aflatoxins.

Traditional crops like millet are available on a limited basis in local markets since most people in Senegal prefer imported rice. Initiatives from the department of agriculture in Senegal have been launched to increase the national production of rice. In 2014, the president of Senegal Macky Sall, launched the *National Program for Rice Self – Sufficiency*. This program aims to increase levels of national rice production in high yielding rice-growing regions of the country like the Senegal River Valley. The objective of the *National Program for Rice Self-Sufficiency* is to reach rice self-sufficiency by producing 1.7 million tons by 2017 (The Economist, 2014). Currently, Senegal continues to rely on rice imports from Thailand and Vietnam, which accounts for close to 40 % of the national production gap (World Food Program, 2010).

Commoditized agriculture is facilitated by established international markets that trade crops that can transport well, are non-perishable, and have low price volatility. Crops like rice, maize, and wheat are produced industrially to reach surplus value on the global market. The dumping of surplus rice from the world market is sold to low-income countries. Senegal's dependence on imported rice makes its national food security extremely vulnerable and it is based on the index for food from the world market. It is

estimated that the average Senegalese adult consumes between 30kg-60kg of rice per year (SWAC, 2011). The 2008 food crisis resulted in extremely high prices for commodity items such as rice, oil, and maize (SWAC, 2011). Senegalese people responded by cutting back on their household consumption of rice to prevent falling into poverty. During the 2008 food crisis, the average Senegalese household spent between 20-25% of their household income on rice (SWAC, 2011). The food crisis pushed millions of Senegalese households into extreme poverty. The global economy's price for commodity food items make low-income countries vulnerable to food insecurity since their primary staples are imported from a distant location. Senegal can regain agricultural dependence and food sovereignty by promoting crops like taro and African rice (*Oryza glaberrima) as* alternative rainy season crops on a national scale.

3. Methods

Target Population

The Crop Diversification with Taro project took place in Guennte gouye, Kaffrine. Guennte gouye is a village located in the Kaffrine region of central Senegal and borders the Kaolack region (see Figure 3.1 and 3.2) The village sits at a latitude $14^0$3.0' N and longitude $15^0$34.0" W, and is 257 km from Dakar. The village is primarily comprised of Wolof farmers who have owned land that was passed down and is generationally inherited. The community is made up of practicing Muslims. Islam is the dominant religion. The village has an estimated population of 150 people (see Figure 3.3 for an aerial view of the village). Guennte gouye was first visited in 2013 by the author. In April 2014, farmers in Guennte gouye had adopted a variety of sustainable agriculture and agroforestry techniques promoted by the Peace Corps. The agricultural seasons are characterized by three distinct periods that consist of the rainy season from June to September, the cool season from October to mid-March, and the hot season from March to mid-June (Massaly, 2013). Local Farmers primarily depend on the crops millet (Pennisetum typhoides), groundnuts (Arachis hypogaea), maize (Zea mays), sorghum (Sorghum bicolor), cowpea (*Vigna unguiculata*), and roselle (*Hibiscus sabdariffa*) crops (Sambou et al., 2016). Agricultural activities and projects with farmers in the village continued with a seed extension project that was created in 2015. In 2015, 26 farmers participated in the ISRA (Senegal Institute of Agricultural Research) Seed extension program and out of the 26 only 15 were selected to participate in the Crop Diversification with Taro.

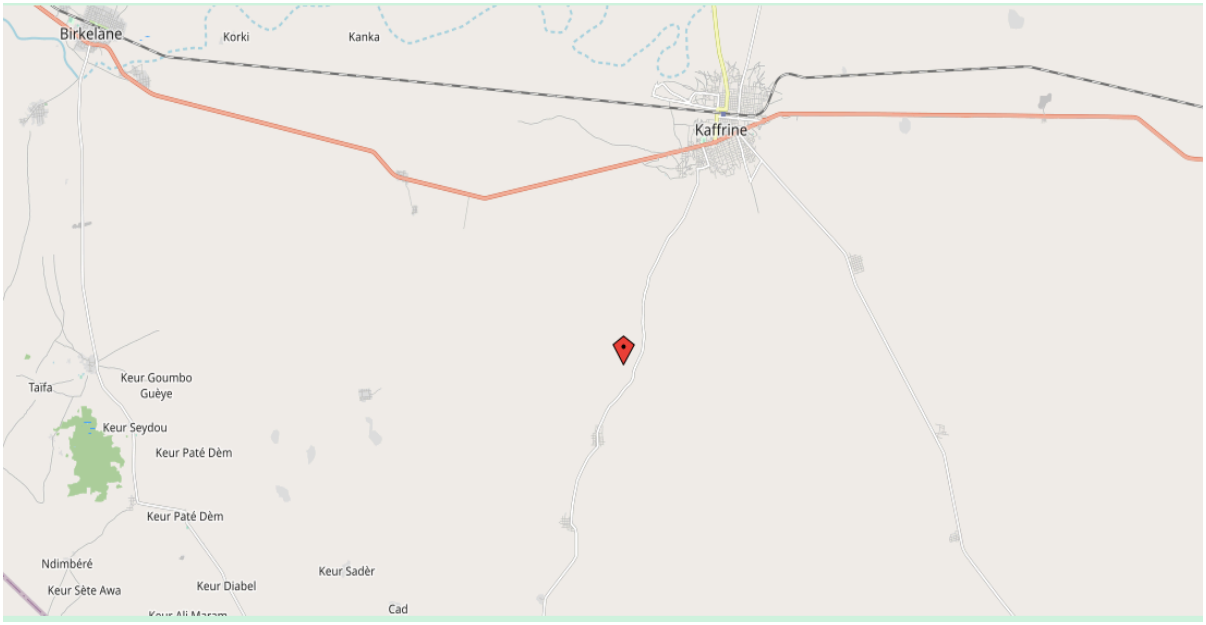

Figure 3.1: Map of Guennte gouye depicting reference from Kaffrine city center (Adapted from Google Maps, 2020)

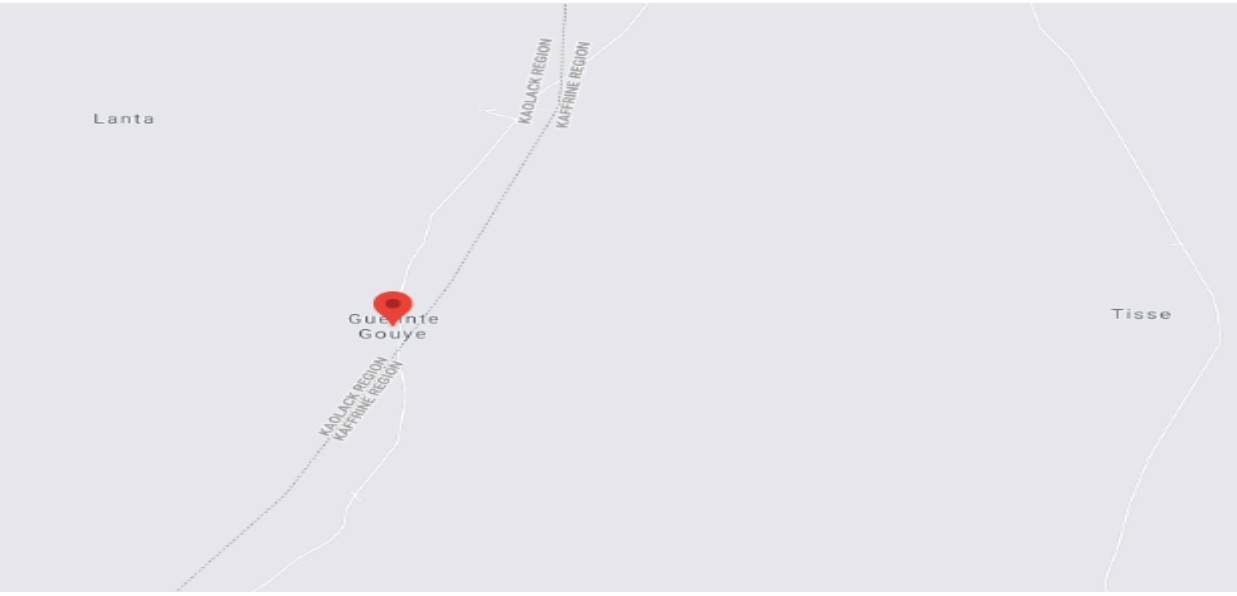

Figure 3.2: Map of Guennte gouye depicting region (Adapted from Google Maps, 2020)

Figure 3.3: Map of Guennte gouye depicting community (Adapted from Google Maps, 2020)

The research approach used to develop the Crop Diversification with Taro root project relied on both qualitative and quantitative methodologies A Literature Review was completed to introduce the scope of knowledge that already existed on taro root. This research paper specifies the ethnobotanical descriptions and local usage of the plant, centering on the way indigenous knowledge on taro has been preserved in Senegal. The ethnobotanical information on taro root was collected by using semi-structured interviews, written notes, and video recordings from field visits in Kédougou. Farmers in the Kaffrine region completed follow-up interviews during a return research trip in 2017 to analyze the factors that lead to the adoption or dis-adoption of taro root. Questions and data included:

1. Cultivation practices and how taro farmers have domesticated the crop for generations.
2. Farmers shared best practices for growing taro root in other regions of Senegal that receive less rainfall.
3. The success/challenge of the taro root project that employed statistical data derived from the rates of taro adoption by farmers in Kaffrine.
4. The adoption rate used to analyze the likelihood of farmers' uptake of an alternative crop.
5. Based on adopters and non-adopters, feedback from farmers' detailing the factors preventing them from diversifying their fields with taro.
6. Use a case study approach to attain in-depth understandings of the benefits and barriers that farmers experience when re-incorporating indigenous crops into their fields.
7. Ranking farmers' preferences in four different locations to understand comparatively how taro stacks up against other crops.

Research Design

Farmers' set aside a small portion of their fields to incorporate taro as an alternative field crop. The research includes a comparison between three different projects that occurred from April 2015 to August 2017. Each subsection of the research project is detailed in three sections: ISRA Seed Extension, Crop Diversification with Taro, and Ethnobotanical Research on Taro. Farmers selected for the study participated in a best practice training for growing taro root to understand how best to cultivate dryland taro. The recommended best practices for growing taro were based on recommendations

and practices of traditional farmers in Kédougou. The research detailing how the ethnobotanical information for growing taro in Senegal was collected in 2015 by collecting data from traditional taro farmers in southern Senegal.

The ISRA Seed Extension project and the Crop Diversification with Taro took place during the 2015 rainy season. 15 out of the 26 farmers that participated in the ISRA Seed Extension program were used to adopt the Crop Diversification with Taro. Only 15 of the 26 farmers were selected to extend taro with the results from these 15 farmers shown in the results chapter.

In 2017, a follow-up research trip to the village Guennte gouye was undertaken to analyze adoption rates of farmers over the intervening two rainy seasons. Each aspect of the three sections has been used as an important aspect of the overall research of Taro and Food Security in Senegal.

A. ISRA Seed Extension program

The ISRA Seed Extension program distributed improved varieties of various crops to 15 farmers involved in the project. A list of the improved varieties is shown in Table 3.1.

Table 3.1: List of ISRA improved crop varieties.

ISRA Improved Crop Varieties		
Variety 1	**Variety 2**	**Crop**
Synthetique C	Suwan	Maize
Melakh	Yachine	Cowpeas
Sorghum CE 145-66	Sorghum CE180-33	Sorghum

Souna 3		Millet
Nerica 1	Nerica 6	Rice

Farmers that received improved verities were required to set up farmer managed demonstration plots to show how well they performed, and in addition the performance of these varieties treated with organic pest control methods compared to chemical inorganic ones (Peace Corps Senegal, 2016). The demonstration plots were 2m x 2m and farmers were required to maintain consistency throughout all plots to ensure accurate yield calculations. Each crop had different spacing requirements. For example, for cowpeas farmers were told to manually seed in rows with a spacing of 50 x 25 cm. Millet was manually seeded with 7-9 grains per plot hole at a spacing of 50 by 45 cm. Sorghum was planted with 7-9 seeds per hole at a spacing of 50 by 30 cm. Corn was planted with 3 seeds per hill at a rate of 50 by 25 cm. Taro was planted at a rate of one corm per mound at improved spacing of 70 by 70 cm. Intercropping was encouraged with taro in farmers' backyard gardens and with field crops planted around the compound but not in the demonstration plots that were used to calculate yields.

B. Crop Diversification with Taro

A total of 15 farmers participated in adopting taro as an alternative rainy season field crop in 2015. The 15 farmers that participated in the project were chosen based on previous meetings with the village chief of Guennte gouye. The first questionnaire consisted of general information about the farmers, including their name, age, telephone number, farm size by hectares, and place of residence. Farmers were interviewed and asked to share information about the arrangement of their cropping system, intercropping

schemes, and traditional knowledge that influence their agricultural practices. Farmers' familiarity with taro as an orphan crop was quantitatively recorded by showing each farmer a series of photos and their answers were documented using familiar or not familiar as a binary code for yes or no. The crops that were shown to farmers included African rice (*Oryza glaberrima*), fonio (*Digitaria exilis),* pearl millet (*Pennisetum glau*cum), bambara groundnut (*Vigna subterranea*), air potato (*Dioscorea bulbifera*), taro (*Colocasia esculenta*) and bitter tomato (*Solanum aethiopicum)*. A questionnaire that surveyed farmers' origin of knowledge about taro was collected to determine how they had first been exposed to the crop. A total of 50 kilos of taro vegetative material was allocated to the project to distribute amongst farmers. Agricultural training on how to best grow taro and incorporate sustainable agriculture techniques took place in the village on June 3, 2015 (see Table 3.2), this table is explained in the results section. The training consisted of reviewing best practices for growing dryland taro based on information collected by taro farmers in the Kédougou region.

C. Follow-Up Research 2017

In 2017, a return research trip to Guennte gouye was arranged to interview the same farmers that originally participated in the 2015 study (Figure 3.4). Three farmers were selected as case studies to understand what primary factors encouraged them to adopt and/or dis-adopt taro root. Two of the three farmers were adopters and one decided to dis-adopt the crop in 2016. The primary tools for data collection were questionnaires to document the factors leading to farmers' adoption or dis-adoption of taro root. Farmers were visited in their field. Data was collected to numerically measure farmers' adoption and dis-adoption rates of taro between the years of 2015-2017. Farmers were also asked

if they shared taro with other farmers they know. Farmer-to-farmer exchange for rural communities' functions as a major source for extending crops.

The 2017 survey was completed by farmer interviews to primarily find out the benefits farmers' experienced from adopting taro. The same survey also included questions that asked farmers to share their main challenges after re-introducing taro. Farmers were then asked to provide open-ended answers and suggestions on what kind of support would be needed to adopt taro as a permanent crop.

Figure 3.4: A taro adopter during his interview exhibiting his intercropping matrix with mango tree, taro and hot pepper during return research trip in the Kaffrine region in Senegal, 2017 (Photo Credit: author)

D. Ethnobotanical Research on Taro in Senegal

Kédougou and southern regions of Senegal has been historically important areas for growing taro in the country. Farmers in the region have been growing it for multiple generations and their knowledge has been used to conserve the crop. Individual in-depth interviews were conducted with farmers in 2017, who in large part have domesticated

wild cultivars of the crop for hundreds of years.

Ethnobotanical information on taro root was captured by field visits and interviews with traditional taro farmers in Kédougou. Agricultural knowledge in Senegal is often derived from local and traditional ways of understanding rather than purely scientific deduction of agricultural scientific theory. Anthropological methods such as ethnography narratives were recorded via video, audio, and written notes in the local language to capture the traditional knowledge on taro root from farmers in Kédougou. An audio recorder was used to record the correct pronunciations and local terminology used to describe taro.

The fieldwork completed in southern Senegal took place during March 2015 and August 2017. In collaboration with Cheikh Anta Diop University, two university students assisted in translating surveys, questionnaires and collecting data during the 2017 research trip. Sites were selected based on preliminary research of ethnic groups that have culturally and historically depended on taro cultivation to maintain subsistence. Sites were also selected based on recommendations from the Department of Agriculture in Kédougou. The region of Kédougou is home to many distinct ethnic groups and is often seen as the stewards of taro conservation in the country. A variety of indigenous ethnic groups inhabit them including Peul Fouta, Jakhanke, Bassari, Bedik, Fulakunda. These ethnic groups function as the major bearers of traditional agricultural knowledge. Their insularity and divergent cultural traditions from the Wolof majority in many ways have acted as a safeguard enabling them to carry on a form of agriculture that has been widely abandoned in other parts of the country.

The methodical approach for collecting emic data from indigenous farmers in Kédougou was completed by visiting their villages for a duration of one to two days. Field visits were carried out with farmers in their fields. By tracking farmers on-field activities for at least half of the day, we were able to put into context and collect data specific to the daily regiment and decision-making that goes into rural agriculture and crop preference. Figure 3.5 shows a traditional taro farmer explaining his intercropping arrangement with taro and maize. The field visits typically started early morning until lunchtime. During the break, time was allocated to engage with family members to understand their role in on-farm activities. When interviewing taro farmers in the village of Dar-Salaam in Kédougou they shared that the heavy rains and flash flooding uprooted the majority of the taro planted during the rainy season of August 2011. Much of the tuber material was carried away during rainy season flooding and limited the amount of genetic material available to replicate planting for the next season. This factor limits the amount of genetic material available, which further pushes taro to be a minor crop. An overwhelming majority of farmers were male heads of households' and exclusively answered questionnaires. We asked to speak to the female head of household farmers in the villages visited, however, we were not able to sample any. To understand the perspective of female farmers, we asked the wives of farmers to partake in the questionnaire to add a layer for understanding of their experience as agricultural practitioners.

Figure 3.5: A traditional taro farmer in Kédougou, Senegal explaining intercropping with maize and taro during research field visit in 2015 (Photo Credit: Author)

E. Ranking Farmers' Crop Preferences

A total of 20 random farmers were interviewed to rank their preferred crops to cultivate. Out of the 20 farmers, only 5 were involved in the Crop Diversification with Taro Project, which are represented as the Guennte gouye respondents. All other respondents are from different locations and are new farmers that did not participate in the project. Five farmers were selected from each location of Kédougou city, Dar Salaam, Kaffrine, and Guennte gouye totaling 20 respondents. All five farmers' rankings from each region were averaged into a mode, the most common number that appeared in the responses. The mode for all of the five farmers is displayed in the results section.

The ranking of farmers' crop preferences was developed by surveying 20 random farmers in four locations. The ranking was used as an analytical tool to demonstrate the perceived importance of different crops. Farmers were asked to rank crops from 1 to 5 with 5 the most important to show their personal preference for the following crops: maize, millet, rice, peanuts, sorghum, taro, and fonio. The ranking value represented "5" as the most preferred and "1" as the least liked. Preference ranking answers were cross-checked with information collected from interviews. The mode, which is the most popular number, was used to represent the preference of that location; if three farmers ranked peanuts 4 in Kédougou City that rank would be represented for the findings in that location. The two locations included rural villages of Dar Salaam and Guennte gouye. The two urban locations consisted of regional capitals Kaffrine City and Kédougou. Two rural communities and two urban centers were selected to represent the differences in crop preferences across rural and urban communities.

Observations

Film and photography were employed as another element of documentation of cropping systems recorded. They added another level of data acquisition to contextualize how taro as an underutilized crop is used in southern Senegal. Photographs acquired during data collection highlight the agronomic benefits of taro as an alternative crop added to field crop systems.

4. Results

The results of the Crop Diversification with Taro initiative are presented in this section along with the finding of the Seed Extension with Senegal Institute of Agricultural Research (ISRA) that took place in 2015.

A. ISRA Seed Extension program

This section consists of the yields of each farmer that participated in the ISRA Seed Extension project. The number of the farmers ranges from 1-15 indicating each participating farmer by a number and their yields. The results displayed in Figure 4.1. show the yields of the crops each farmer grew.

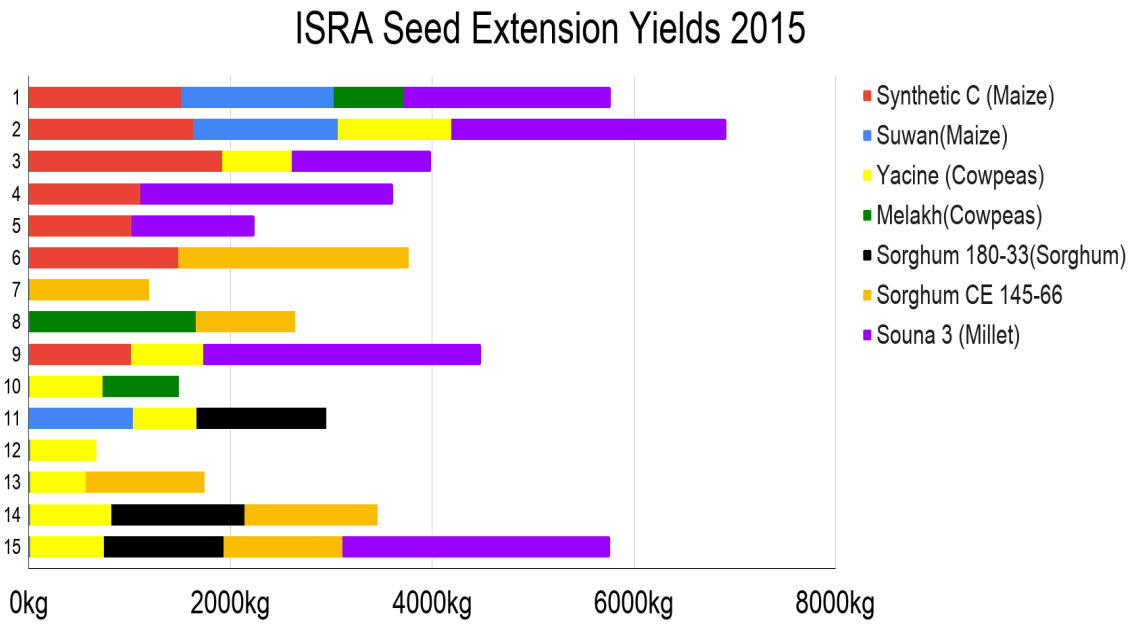

Figure 4.1: Graph illustrating yields from ISRA 2015 Seed Extension of all the crops grown by each farmer. Farmers were numbered from 1 to 15 on the Y-axis and X- axis relative yields.

The following figures show the yields that farmers obtained from the crops they decided to grow. Figure 4.2 shows the yield data from the 7 farmers who grew Souna 3. The findings indicate that farmers that cultivated Souna 3 millet reported the highest yield for grain type.

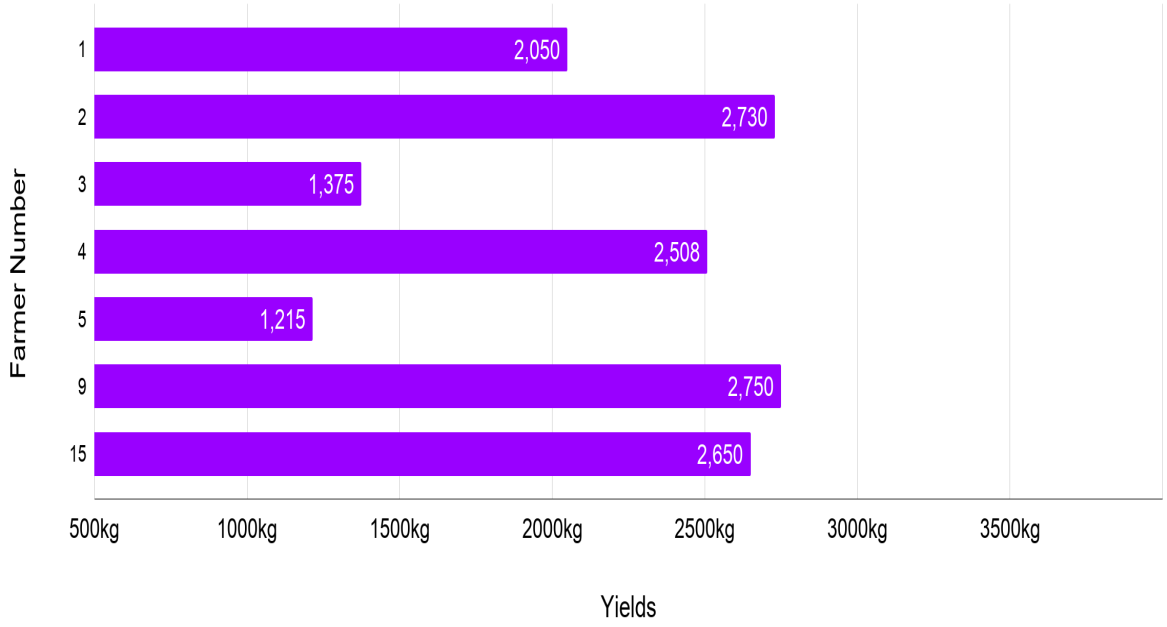

Figure 4.2: Souna 3 millet yields of farmers that grew this cereal crop. The average yield from the 7 farmers growing millet was 2,182 kg.

The lowest yielding cereal grain was Sorghum 180-33 shown in Figure 4.3 the 3 farmers that chose to grow this variety have a history growing this crop.

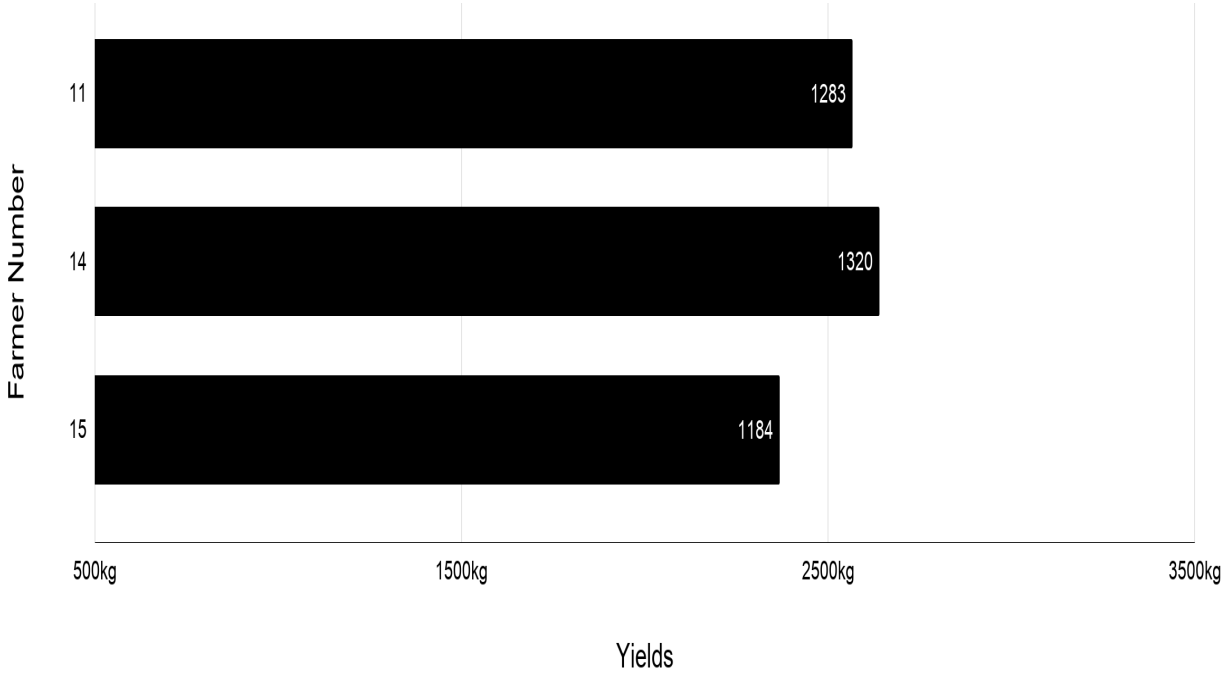

Figure 4.3: The yields Sorghum 180-33 (Sorghum) from the 3 farmers who chose to grow this cereal. The average yield from these 3 farmers is 1,262 kg.

Sorghum CE 145-65 millet was reported as the second-highest yielding crop and farmers were particularly pleased by the relatively early harvest date.

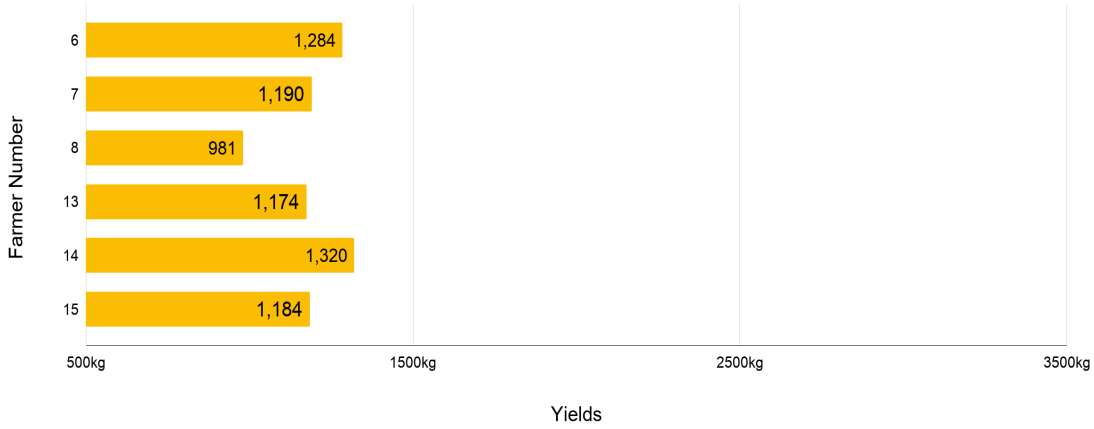

Figure 4.4: Sorghum CE 145-65 millet was the second-highest yielding crop. The average yield from these 6 farmers is 1,188 kg.

Synthetic C Maize had the third-highest yield amongst farmers in the program. This was the most praised crop out of all of the ISRA varieties. Farmers adored the big kernels this variety produced.

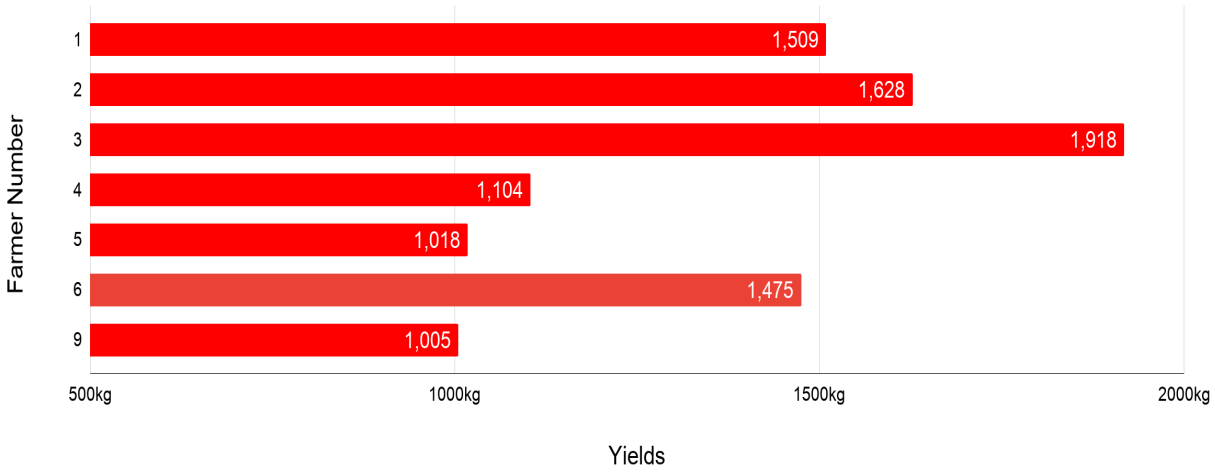

Figure 4.5: The yields of Synthetic C (Maize) by the 7 farmers that grew this cereal. The average yield for this crop by the 7 farmers growing it was 1,379 kg.

Suwan Maize was only extended to a few farmers. The kernels for this variety were yellow rather than white like the Synthetic C variety.

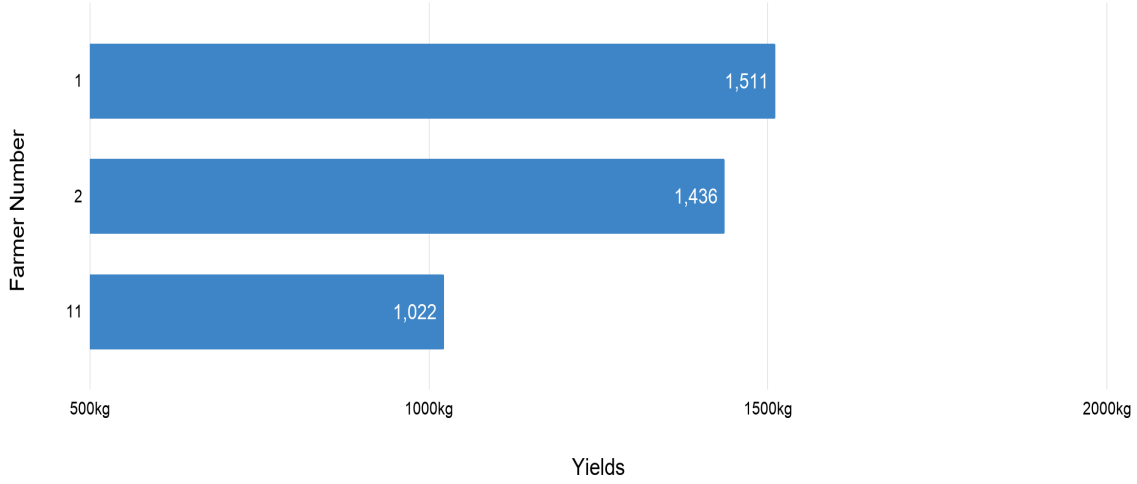

Figure 4.6: The yields of Suwan C Maize grown by 3 farmers. The average yield for this crop grown by the 3 farmers was 1,323 kg.

Two legume crops were given to farmers and the data from the farmers that grew these two crops are shown in figures 4.7 and 4.8 below. The highest yield for cowpeas was 925 for Yacine and 950 for Melakh .

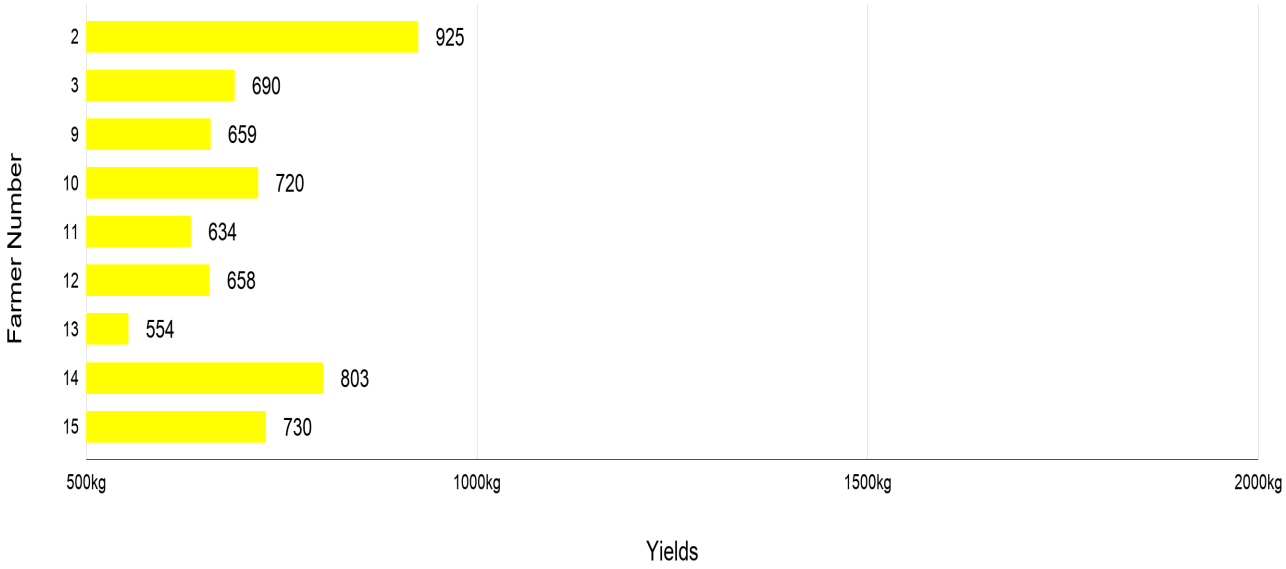

Figure 4.7: Graph demonstrating yields of farmers that grew Yacine (Cowpeas). The average yield for this crop grown by the 9 farmers was 615 kg.

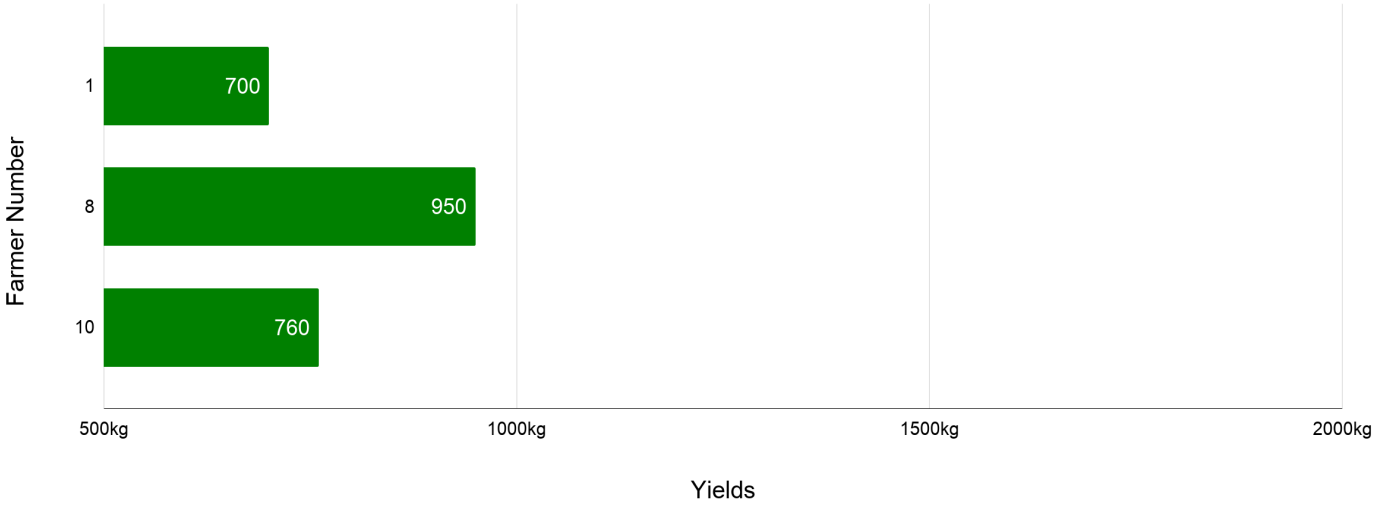

Figure 4.8: Graph demonstrating yields of farmers that grew Melakh (Cowpeas). The average yield for this crop grown by the 3 farmers was 803 kg.

B. Crop Diversification with Taro 2015

The following shows the yields of each farmer that participated in the Crop Diversification with Taro project. Figure 4.9 shows the data from 2015, when all farmers adopted taro. Farmers 1, 2, 5, 6, and Farmer 15 continued to grow taro in 2016 and Farmers 1 and 2 were the only the farmers that continued to grow the crop in 2017.

The average reported yield for taro grown in 2015 was 3.8 kg, which is 1.8 kg more than what was originally given to them. The yields obtained by each farmer in 2015 is shown in Figure 4.9.

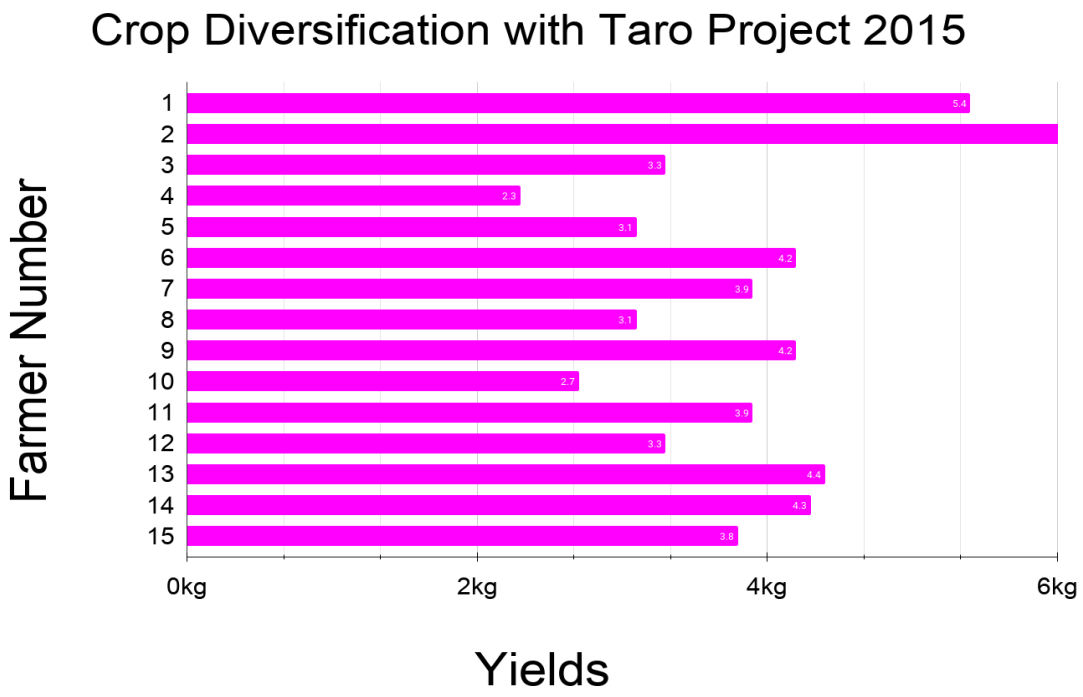

Figure 4.9 Graph demonstrating taro yields of 15 farmers that participated in Crop Diversification with Taro 2015 project. The average yield for taro grown by farmers was 3.8kg.

A number of recommendations were given to farmers on how to best grow taro. The recommendations are listed in Table 4.1. The following are the results of farmers' adherence to the recommendations. Timely planting of dryland taro is critical since it is a rainfed crop. Out of the farmers involved in the program, 8 out of 15 (53%) reported planting corms immediately after the first rains arrived. The other 7 planted the corms later. An estimated 2 kilos of taro is approximately 30 corms. One participating farmer obtained less than 2 kilos of taro to cultivate due to constraints of arable land. Although not required, farmers were recommended to plant corms using raised mounds, 9 out 15 farmers (60%) utilize raised earth for less weed competition and bigger quality corms. Farmers in Kaffrine often use manure or compost to prepare soil before planting a new crop. 14 out 15 (93%) of the farmers used compost and planted corms into fresh soil. For dryland taro, weed management is one of the most laborious tasks. Farmers were recommended to weed every 60 days for three months in intervals of 60, 160, 180 days. A total of 11 out of 15 (73%) farmers maintained this weeding routine. As a root crop, spacing is important for taro to achieve high quality corms. A total of 9 out of 15 (60%) farmers spaced taro with at least 70 cm apart. The last recommended activity was intercropping. Taro can often be intercropped with other crops. Some farmers intercrop taro with vegetables such as eggplant, okra, and bitter tomato. A total of 12 out 15 farmers (86%) intercropped taro with field crops or vegetable crops in their compound gardens in the designated area allocated for rainy season field crop production.

Table 4.1: Number of farmers (15 total) that performed recommendations and best practices after participating in the sustainable agriculture training in Guennte gouye, Kaffrine (2015).

Adherence to Improved Agricultural Techniques s for Taro	Number of Respondents	Percentage of Adherence
1. Corms planted at the onset of first rains of the rainy season	8	53
2. Farmers cultivate at least 2 kilos of taro vegetative material in o cropping system during the rainy season of 2015	14	93
3. Develop raised mounds to maintain wider plant spacing of taro	9	60
4. Land preparation – plant corms in soil with high soil organic matter, compost, manure or decayed leaf foliage	14	93
5. Weed management every 60 days within 3 months of transplanting into cropping system	11	73
6.Improved spacing of 70 cm by 70 cm per taro planted into cropping system	9	60
7.Intercropped taro with other common rainy season field crops	12	86

Overall, the majority of farmers were able to implement recommended agricultural techniques to optimize the production of taro in 2015. There is a correlation between farmers who implemented the recommendations and then adoption. The farmers that practiced all recommendations were more likely to adopt taro. Out of the 15 farmers, the 2 farmers that practiced all recommendations were also the ones that continued to cultivate after the extension project was complete.

The 15 farmers involved in the 2015 taro project were asked to share their first point of reference to taro and other underutilized crops. Taro and other underutilized crops are not commonly known in the Kaffrine region. These crops are largely considered lost crops and are absent from the present cropping systems of central Senegal. Taro is

regionally underutilized and is considered orphaned. Farmer-to-farmer knowledge is an important way to promote and disseminate information on underutilized crops. Farmers act as sources of knowledge and are involved in sharing agricultural information. These knowledge exchanges can promote underutilized, indigenous crops in this region.

Farmers provided information on how they first came into contact with taro and other underutilized crops. A total of 11 out of 15 farmers sampled claimed that they learned about taro and other underutilized crops from ethnic minority groups in Senegal. Many of the ethnic groups that farmers cited are nomadic and travel across Kaffrine carrying crops culturally important to them. Farmers that learned of taro from other ethnic groups in Senegal mentioned the following ethnic groups; Peul Fouta, Jakhanke, Bassari, Bedik, and Fulakunda that are all from southern Senegal. An additional 2 out of 15 farmers claimed their knowledge on taro and other underutilized crops came from "Trees for the Future" a nonprofit NGO with a mission to end hunger and poverty by training farmers on how to regenerate their land. One of the 15 farmers mentioned traveling to regions in Senegal that cultivate taro and other underutilized crops as their source for knowledge. Lastly, one farmer said their source of taro knowledge came from agricultural extension workers. This information is presented in Figure 4.10 and summarizes the sources of farmer's knowledge on Taro and Crop Diversification with other underutilized crops.

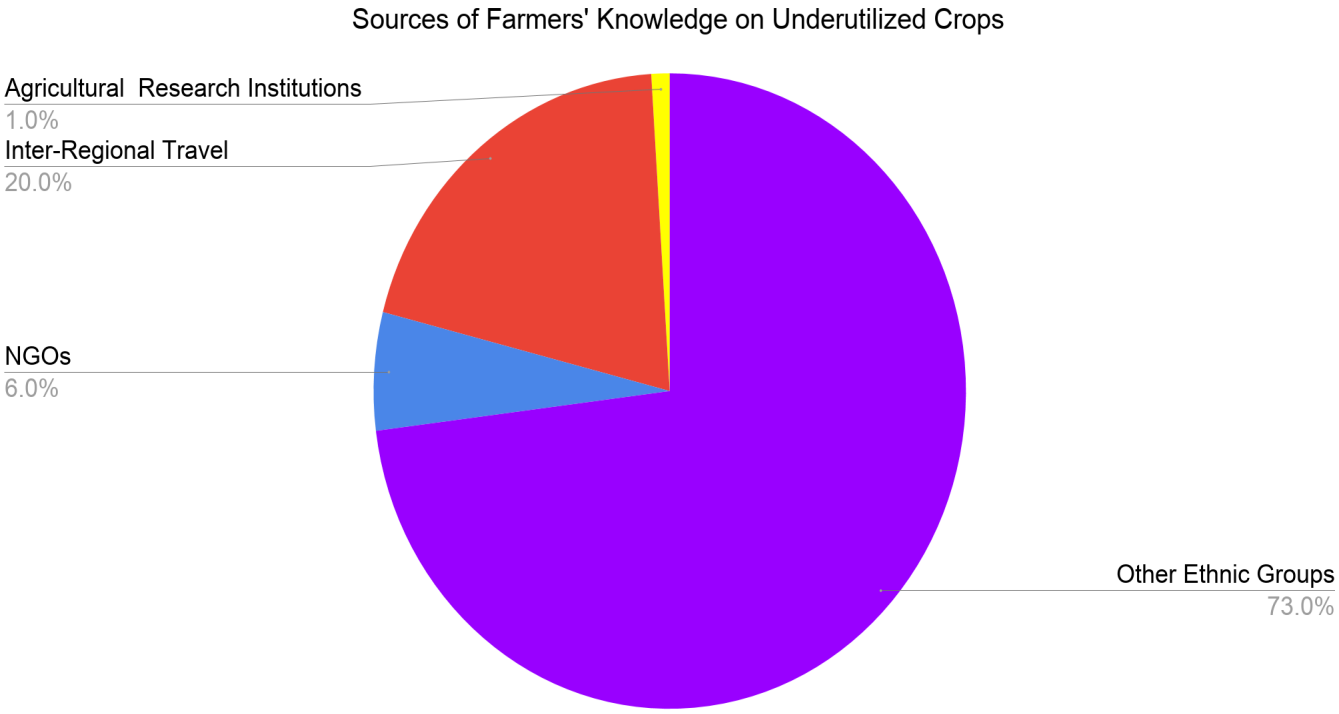

Figure 4.10: Sources of farmers' Knowledge on taro and underutilized crops.

Underutilized Crops

Farmers' familiarity with taro and underutilized crops was determined by conducting surveys to gain a better understanding of their prior knowledge of minor crops. All 15 farmers participated. The seven crops that farmers were asked to identify are commonly known as orphan crops internationally. Examining farmers' level of familiarity with lesser-known crops was conducted by showing photos of seven crops indigenous in Senegal. Farmers were asked to identify the seven crops as familiar or unfamiliar. The crops used in the survey were African Rice **(***Oryza glaberrima*), Fonio (*Digitaria exilis*), Pearl Millet (*Pennisetum glaucum*), Bambara Groundnut (*Vigna subterranea*), Air Potato (*Dioscorea bulbifera*), Taro (*Colocasia esculenta*) and Bitter

Tomato (*Solanum aethiopicum*). Figure 4.11 shows the outcomes. The findings show that Pearl Millet is well-known amongst all farmers. Other orphan crops that were familiar amongst the 15 farmers were African Rice, Taro, Bambara Groundnut, and Bitter Tomato. The only crop that was not familiar amongst farmers was the Air Potato. Out of the 15 farmers, only 9 were familiar with Air Potato. Only one farmer was not familiar with fonio, an indigenous staple grain common in southern Senegal.

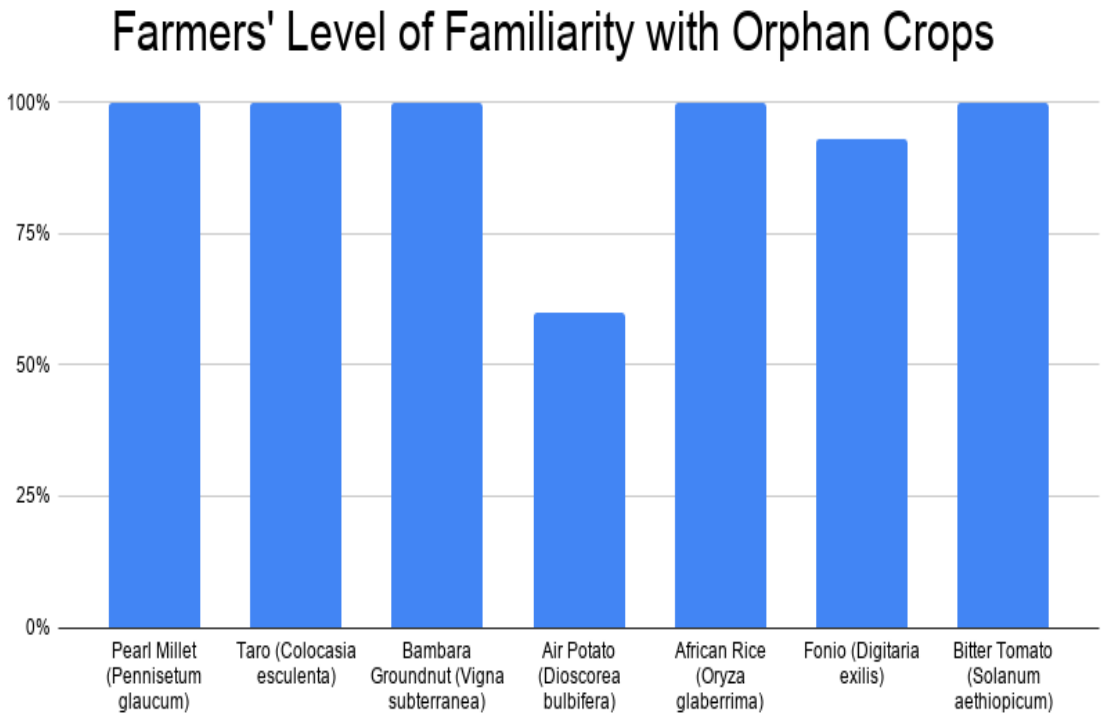

Figure 4.11: Farmers Familiarity with Orphan Crops.

Farmer Household Data in Relation to Adoption of Various Crops

The relationship between farmers' age and land size influences adoption rates. All farmers that participated in the 2015 study were head of households and functioned as the

lead decision-maker for selecting crops to grow in their household each season. The age of participating farmers in the study range between 29 to 70 years old. The average age was 45 years. The largest age group consisted of six farmers between the ages 35-44 years old. The average amount of farmland owned by all farmers in the study was 2 hectares. The largest amount of hectares possessed by a farmer in the study was 5 hectares. Figure 4.12 indicates the number of farmers in each age group and the average amount of land each age group owns. Farmers between the ages of 26-34 on average owned 1.5 hectares of farmland. The most populous age group of farmers, 35-44, on average owned 2.2 hectares of land. Farmers that were 45-54 owned 2.4 hectares. Those between the ages of 55-64 had 2.7 hectares of land. Only one farmer was in the age group 65-74 and owned 5 hectares of land.

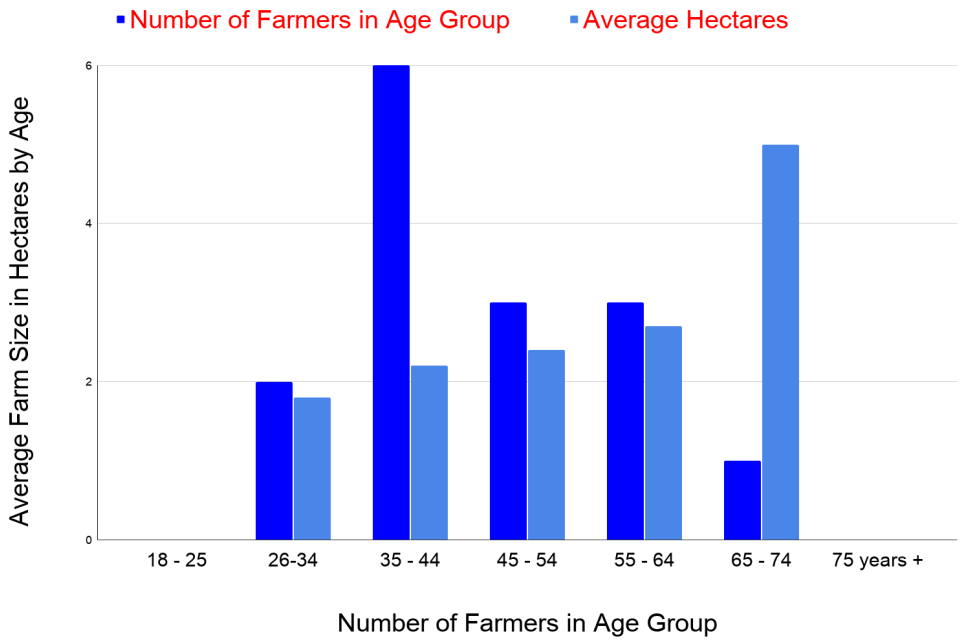

Figure 4.12: Average Farmers' Age and Average Farm Size

Out of a total of 15 farmers that participated, only 1 was female which is represented as farmer 12. Female farmers in Senegal face an array of challenges. Women have fewer resources and make limited decisions in what crops to grow for the household. Women are often allocated tasks such as weeding and selling the harvest in local markets. The extent of this research project did not focus on the unique challenges women that participate in the agricultural sector of Senegal experience. The lack of female farmers involved in the project to be selected by the chief of the village is a testament to the disparities that women experience in the agricultural sector. During the project, the sole female farmer was discouraged from growing corn and was persuaded to only sign up for cowpeas and taro. The apparent truth is that only one female farmer was selected to participate in the seed extension and crop diversification with taro root.

C. Follow-Up Research Results in 2017

4.1 Adoption and Dis-adoption of Taro

The results suggest that over the duration of two rain-fed agricultural seasons in Guennte gouye, Kaffrine, only 2 out of 15 farmers continued to cultivate taro as an alternative field crop during the rainy season of 2017. The remaining 13 farmers provided with vegetative seed material in 2015 decided not to grow taro, to dis-adopt taro, resulting in a decrease in total farmers in the region growing it. The dis-adoption over the 2 years after the extension project can be linked to a variety of limitations including relatively late planting of corms after the first rains. All farmers reported dense weed competition and inadequate demarcation of the taro crop after it was initially grown and challenging for farmers to distinguish where it was planted after the first year. Dryland taro has a tendency to be overgrown with weeds if not managed properly. Figure 4.13

illustrates the adoption and dis-adoptions of taro root between 2015- 2017. Limitations on the available labor needed for weeding dryland taro was also reported as a cause for dis-adoption. Many farmers depend on their family members to help manually weed crops. The lack of agricultural labor made it difficult to continue to cultivate taro.

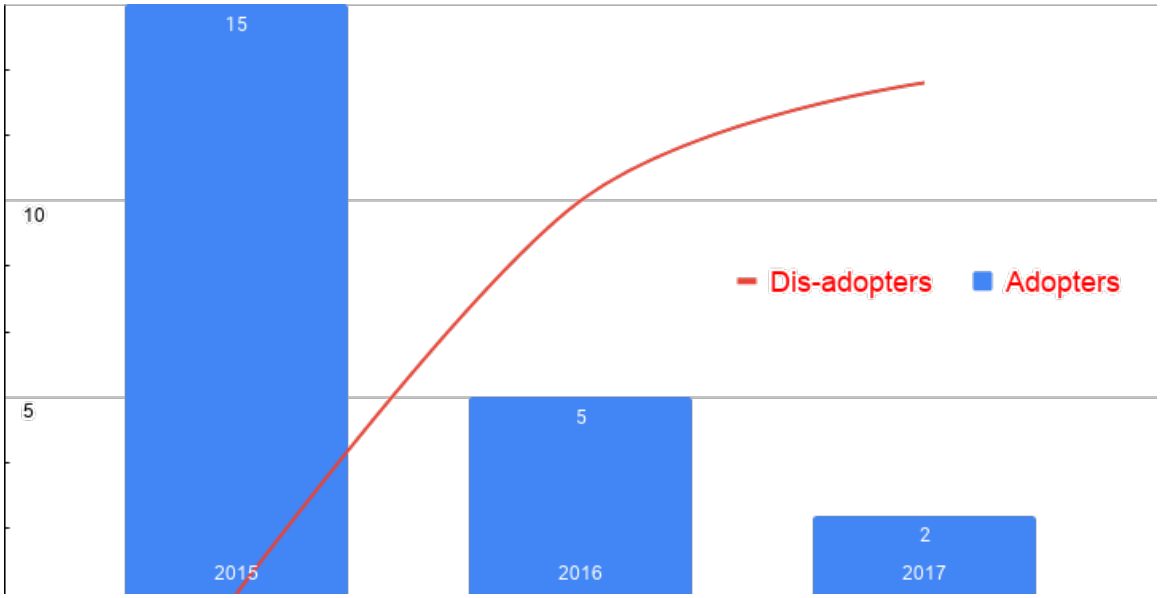

Figure 4.13: Adoption and Dis-adoption of Taro from 2015 -2017

4.2.Farmer-to-Farmer Taro Extension

The results indicate that farmers that participated and adopted taro root during the first year of extension functioned as local seed banks for vegetative corm material. During the first year of adoption, many farmers not participating in the extension project were interested in obtaining more information about taro. Adopters of taro acted as knowledge hubs for sharing information on crop diversification with taro in the region. Data shown in Table 4.2 indicates that since 2015 there has been an annual increase of new farmers growing taro in the Kaffrine region. Farmers were asked if they had

distributed taro corms to other farmers they knew. In 2015, a total of 6 new farmers had corms extended to them. A total of 3 new farmers were given taro corms in 2016 and one new farmer got corms in 2017. Overall, 10 farmers received taro root in these three years via the farmer-to-farmer extension.

Table 4.2 Number of farmers that adopted and extended taro to other farmers and the aggregate of farmers who acquired taro from farmers that participated in project.

Year	2015	2016	2017
Number of new farmers to acquire taro corms each year	6	3	1
Aggregate of farmers who acquired taro from farmers that participated in project.	6	9	10

4.3 Preferred Crops Cultivated by Farmers

In 2017, 20 farmers were asked to rank their most preferred crops. 5 of the 20 farmers participated in the Crop Diversification with Taro 2015 project – these farmers represent the Guennte gouye location. The rest of the 15 farmers were chosen at random from other locations.

The result from this ranking shows that farmers in all of the locations that maize (*Zea mays* L) was the most important crop for farmers to cultivate. Figure 4.14 illustrates the ranking results. Peanuts (*Arachis hypogea*) were ranked a close second in Kaffrine and Guennte gouye, all participating farmers in this region ranked maize and peanuts as

equally important. Pearl millet (*Pennisetum glaucum*) and Sorghum (*Sorghum bicolor*) were ranked as equally equivalent; millet by a slight margin was preferred more than Sorghum. Kédougou region receives higher levels of annual rainfall, which may have impacted its preference for rice and maize as a highly ranked crop to cultivate in Dar Salaam and Kédougou. Taro (*Colocasia esculenta* L) , and fonio (*Digitaria exilis*), which are both underutilized crops in Senegal, were the least preferred crops in Kaffrine City and Guennte gouye. In the village of Dar Salaam and Kédougou, both crops were highly preferred, likely due to their cultural importance regionally in southern Senegal.

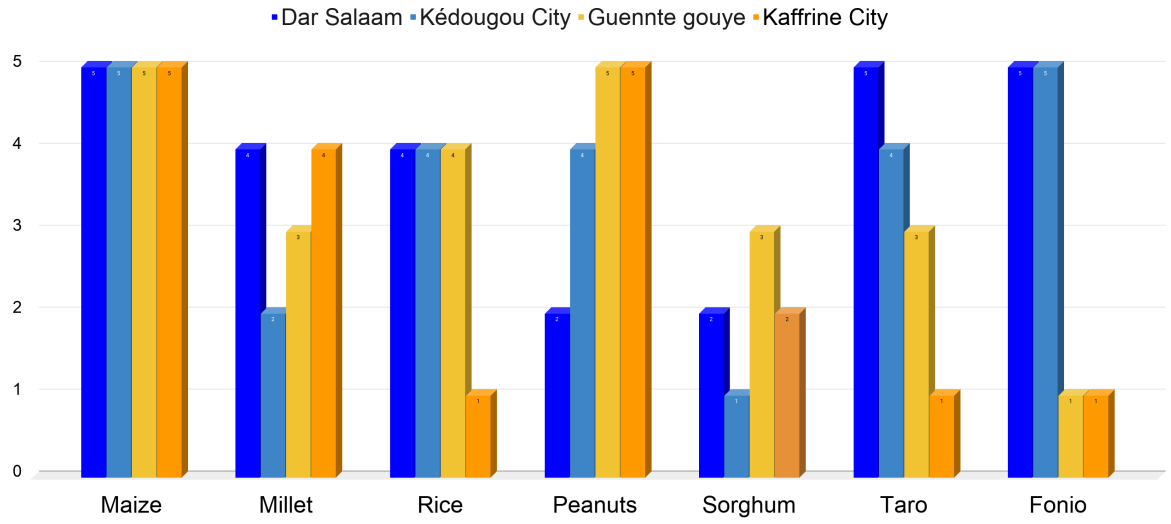

Figure 4.14: Preferred Crops to Cultivate Ranking in Kaffrine and Kédougou
5= most important; 1= least important

4.4 Factors that led to Taro Adoption and Dis-Adoption

During the 2017 Follow-Up research trip, the same 15 farmers who received taro in 2015 were asked what had happened to their taro plots. The first question that was asked to all adopters was what factors lead them to continue to grow taro. The primary factors leading to continued adoption of taro is outlined in Table 4.3. Non-adopters and adopters

provided feedback on the early benefits they experienced after introducing taro as an alternative field crop. 90% of farmers cited using taro leaves as livestock fodder to feed their animals. Another 72% claimed taro was beneficial for agricultural diversification and intercropping. Taro's minimal pesticide usage to grow taro successfully was mentioned by 81% of farmers. The low cost of growing taro was mentioned as a benefit by 63 % of farmers. In addition, low maintenance after the initial first 3-6 months of cultivation was cited by 54% of farmers as an advantage. Overall, dryland taro experiences minimal pest problems and this was a perceived benefit observed by 18% of farmers. Around 9% of farmers cited as benefit for growing taro was its ability to be uprooted and consumed months later. Only 9% of farmers cited improved nutrition as an incentive for growing taro.

Table 4.3: Factors Leading to Taro Adoption

Factors Leading to Taro Adoption	**N=11**	**Percentage of total respondents**
Livestock fodder	10	90
Agricultural diversification	8	72
Minimal pesticide usage	9	81
Low cost of implementation	7	63
Low maintenance	6	54
Limited pests and diseases	6	18
Alternative rainy season crop	1	9
Improved nutrition	1	9

Many challenges exist that prevent farmers from incorporating taro into their cropping system. Farmers were asked to cite major barriers that prevented them from adopting taro long-term. During the 2017 Follow-Up research trip dis-adopters were asked why they decided to dis-adopt taro root. The primary reasons leading to taro dis-adoption are outlined in Table 4.4. Farmers provided several reasons why they dis-adopted taro after growing it initially in 2015. 8 out of the 11 farmers claimed that the association of taro with ethnic minorities such as the Pulaar ethnic group in Senegal was a major reason for dis-adoption. 5 out of 11 farmers mentioned that taro's association with poverty and reputation, as a poor person's crop, was a factor for dis-adoption. The presence of calcium oxalate crystals in taro was cited by 4 out of the 11 farmers as one of the factors to make it a challenging crop to adopt. 10 out of 11 farmers cited market value as a limitation. While 5 out of 11 farmers claimed, that prolonged cook time to boil taro down to an edible state functioned as a constraint. 1 out of the 11 farmers reported a lack of detailed knowledge and unfamiliarity with taro as a cause for dis-adoption. A concern raised by farmers, which functioned as a factor for its dis-adoption was that it was not a crop promoted by reliable agricultural institutions. 8 out of 11 farmers claimed that the poor infrastructure for marketing was a barrier for adoption. Behavioral change factors encompass a multitude of meanings, 1 out of the 11 farmers cited a reluctance to change as a reason for not adopting taro. 6 out of 11 farmers claimed a lack of labor to carry out agronomic activities as a constraint for adopting taro as an alternative rainy season field crop.

Table 4.4: Factors Leading to Dis-Adoption of Taro

Factors Leading to Dis-Adoption of Taro	**N=11**	**Percentage of total respondents**
Association with ethnic minority	8	72
Perceptions of taro with poverty	5	45
Age	2	18
Calcium oxalate crystals in taro	4	36
Market value	10	90
Cook time	5	45
Farmer knowledge on taro	1	9
Limited promotion by institutions	3	27
Poor infrastructure for marketing	8	72
Behavioral change	1	9
Labor	6	54

4.5 Agricultural Support Required for Continued Taro Adoption

A total of 10 additional farmers that did not participate in the Taro Crop Diversification Project adopted taro and were willing to incorporate it in their cropping system. The willingness and enthusiasm of farmers outside of the project reflect the need for additional resources and materials to support the re-adoption of underutilized crops. During the 2017 follow up research the farmers were asked to provide insight on what kind of agricultural support they would need for long-term adoption of taro and other underutilized crops. Table 4.4 shows the kind of support farmers need for the long-term

adoption. The research study answers are from the same farmers that originally participated in the taro and seed extension project in 2015 as displayed in Table 4.5.

Table 4.5: Agricultural Support Required for Continued Taro Adoption

Agricultural Extension Initiatives required to increase adaption of underutilized crops	**N= 15**	**Percentage of Responses by Follow-Up in 2017**
Vegetative corm seed material	1	6
Extension and advisory services on conservation of underutilized crops	4	26
Training on conservation	11	73
Access to land	1	6

The need for vegetative corm material to cultivate taro was not mentioned as a major constraint to adopt taro, it was cited by only one farmer. Another 26% of the farmers referenced the need for agricultural advisory support through extension workers to properly utilize and conserve taro from previous seasons. The training was reported to be the most needed area of support, with a total of 73% of farmers citing training as an initiative that would help them understand the importance of farmer conservation of underutilized crops. Lastly, one farmer reported access to more land as a need for growing taro.

D. Ethnobotanical Research on Taro in Senegal

4.1 Case Studies

The Crop Diversification with Taro project involved farmers that decided to adopt and dis-adopt the crop. The following three case studies were developed to collect more information on the factors that encouraged or deterred farmers from growing taro. Case studies were collected in 2017 when the author returned to the village to follow-up with the same farmers that participated in the 2015 study. It features two farmers that continued to grow taro and one farmer that dis-adopted the crop in 2016. All three case studies illustrate key benefits from incorporating taro as an alternative, while also explaining real drawbacks experienced by farmers.

Case # 1. Adopter – Bobacar Wilane "Agroforestry and taro root as shaded plant," Guennte Gouye, Kaffrine.

Bobacar Wilane is 43 years old and is one of the leading farmers in Guennte gouye. His family consists of his wife and six children. He owns 2 hectares of farmland that used to grow field crops. During the rainy season, he also maintains two small gardens that grow squash, eggplant, bitter tomato, and hot pepper. The family has one mule, which is used to transfer inputs such as compost directly onto the field. When asked about what factors lead him to continue to grow taro he said, "it feeds itself; after planting taro there is very little work needed to make it grow. The height of the plant helps give shade to other vegetables. After the first year of growing taro, if the soil is good it will emerge again." Out of all of the farmers to participate in the Crop Diversification with Taro project, Bobacar grew the most diverse crops and maintained a tree nursery. He is represented as Farmer 1 in the yields figures section in Figure 4.9 above. He has collaborated with many different NGOs and government extension projects.

Photo 4.1: Bobacar Wilane standing in a field planted with taro, in the Kaffrine region of Senegal, 2017 (Photo Credit: author)

Case # 2. Adopter - Sidy Wilane "An Easy Breakfast," Guennte Gouye, Kaffrine.

Sidy Wilane is 48 years old and owns 4 hectares of land (see Photo 4.2). He primarily grows peanuts, corn, cowpeas, and millet each year. He cultivates field crops only during the rainy season and depends on his harvest and storage units to preserve his yield throughout the year. His family consists of two wives and a total of 11 children. In the Crop Diversification with Taro project in 2015, he is Farmer 2 in Figure 4.9 above. In 2017, Sidy's field was revisited when asked what were the benefits and disadvantages to growing taro he stated, "it is a good breakfast food. I can feed it to my family when there is not enough bread. All I do is put pepper on it and it is ready to eat. I used to eat taro when I was younger and when I spent time in Tambacounda." When talking with Sidy about difficulties associated with growing taro he said "In this area it is

not a custom for Wolof people to eat this crop. When people see that I am growing a Peul crop they associate me with this group. I have many friends who are Peul and they have given me advice about different ways to cook it, however for Wolof people it is uncommon."

Photo 4.2: Field Visit captured Sidy Wilane and his children standing beside backyard taro plot Kaffrine region in Senegal, 2017 (Photo Credit: author)

Case # 3. Dis-Adopter – Momadau Cisse "A Crop With No Importance," Guennte Gouye, Kaffrine, #Farmer 5

Momadau Cisse is 50 years old. His farm is on slightly elevated land with small pebbles that have not been weathered down to soil. He owns 1.5 hectares of land. Momadau devotes most of his land to grow peanuts and maize during the rainy season. During the off-season, his wife helps him sell any extra crops in the local market. The family consists of his wife and two children. Momadau participated in the Crop Diversification with Taro project in 2015 and he is represented as Farmer 5 in Figure 4.9 above. He decided to continue to grow taro after the initial extension season, but then dis-adopted it in 2017. When asked about his experience-growing taro Momadau said, "my land is little and each seed crop I grow has to have many purposes. Taro

does not have much importance for me because I can only eat it with one meal, not all." One of the major reasons he decided to stop growing taro was to continue to grow more maize which he uses to feed his family for all three meals and sell any excess. Photo 4.3 shows Momadau with one of his children.

Photo 4.3: Field Visit to Momadau Cisse's farm. In 2017 he decided to not grow taro and cultivate a peanuts and maize matrix. Kaffrine region in Senegal, 2017 (Photo Credit: author)

E. Photos of Taro in farmer fields

Photo 4: A backyard garden of a traditional taro farmer's in Kédougou 2017 (Photo Credit: author).

Photo 5: Taro intercropped with hot pepper during an adopter's field visit to Guennte Gouye**,** 2017 (Photo Credit: author).

Photo 6: Taro plot during Crop Diversification training that took place in Guennte Gouye**,** 2015 (Photo Credit: author).

Photo 7: Bobacar Wilane taro production system. He primarily grows taro to harvest the leaves. Taro adopter follow-up visit in Guennte Gouye**,** 2017 (Photo Credit: author).

Photo 8: Traditional taro farmers grow taro using peanuts shells as mulch. Photo was taken during a field visit to a Jahanke village growing taro in Kédougou, 2014 (Photo Credit: author).

Photo 9: Example of taro being grown close to living quarters in traditional Peul Fouta taro production system in Kédougou, 2015 (Photo Credit: author).

Photo 10: Taro being grown in a shady environment in the backyard of a traditional taro farming household in Kédougou, 2017 (Photo Credit: author).

Photo 11: The author after a field visits in Guennte Gouye, 2017 (Photo Credit: author).

Photo 12: A rare look at highland taro up in the Fouta Djallon, Guinea. Taro is grown as a kitchen garden crop close to village living quarters, 2015.

5. Discussion

Achieving food security encompasses multiple pathways of interdisciplinary research. When considering the ways taro can facilitate the process of attaining food security, it is important to analyze previous research. This chapter provides a comparison of what past researchers have said about taro and how it relates to the findings in this paper. Using previous research helps to better understand the importance of underutilized crops. This discussion is based on the implications of the results and comparing it to previous writings on taro, which were highlighted in Chapter 2, the Literature Review. This discussion is also based on the 2017 research follow-up, and functions as a broader discussion on information collected during farmers interviews.

A. ISRA Seed Extension

The ISRA Seed Extension results exposes many relevant suggestions regarding farmers' performance and seed preferences. Although participating farmers selected different varieties and crops to cultivate from the extension list, our findings indicate that the farmers relative performance for the ISRA Seed Extension is associated with how much taro they produced. In general, farmers that produce higher yields of ISRA field crops also produce higher yields of taro. This may be related to their soils being better. Several agricultural variables produce differences in farmers' yields. These differences are fundamentally related to farmers' performance and agricultural practices. There are noticeable differences between the yields of farmers growing the same crops. In general, farmers that adhered to the recommendations of improved spacing between crops and weeded every 60 days reported higher yields. Surprisingly, only 7 farmers grew Synthetic C (Maize) although it was the most popular crop amongst farmers and was grown in

almost every field during the Follow-Up visit in 2017. The photo in figure 5.1 illustrates how widely Synthetic C was cultivated in Guennte gouye in 2017. This could be a result of this maize variety seed being available for planting.There is a correlation between farmers that produced high yields of ISRA crops and high yields of taro. Both of the final adopters in 2017 reported relatively high yields for all crops. In many ways, these two farmers also represent a shift from farmers that practice improved agriculture and those that do not. The two adopters, when compared to the other farmers, had incorporated many principles of sustainable agriculture. They also accepted technical recommendations from agricultural extension workers and NGOs. The biggest factor between high yielding farmers and others would be soil quality and adherence to the recommended spacing and weeding.

Figure 5.1: Synthetic C extended maize cultivated extensively during the 2017 returned visit.

B. Crop Diversification with Taro

The yield results for taro highlight an interesting trend amongst all the farmers that initially adopted it. All farmers received 2 kilos of taro vegetative material and by the end of the rainy season had produced more. The increased production of taro indicates that if farmers continue to plant taro as an alternative rainy season field crop a steady production of taro corms and leaves can be achieved for household consumption. As an alternative crop meant to supplement the diet when other crops fail, taro has the ability to be stored in the ground and can be uprooted when needed before the hot season when other food crops are not available. Other crops often require expensive storage structures to conserve grains. Previous researchers have shed light on the ability of taro production to be used during times of hunger. Jaw-Kai Wang and William Steinke (1975) research explains that a constant production output could be achieved but is dependent on seasonal variation. Irrigation systems and a water supply to nourish taro is an important aspect for growing it year-round. In Senegal, a short rainy season makes year-round taro production very unlikely, however, farmers can still continue to grow taro planted from the rainy season and store it until the hot season for consumption.

Adherence to Improved Agricultural Techniques Recommendations for Taro Cultivation

Sustainable agriculture emphasizes increasing food security through regenerative and ecological conscious methodologies. All of the farmers participating in the project depended heavily on chemical pesticides and fertilizers to increase their harvest. The training on improved agricultural techniques for taro cultivation were developed with the tenets of sustainable agriculture in mind. The results suggest that although all farmers

incorporated the recommendations, there is still reluctance with believing in the principals of sustainable agriculture as being effective. Many farmers insisted on continuing to use Urea chemical fertilizer although they had already planted taro corms in compost soil. This suggests that there is hesitancy by farmers to accept recommendations that are non-chemical and slow acting. One of the key recommendations for the project was for farmers to plant corms at the onset of the first rains. As a rain fed crop, taro depends on a rainy season, which is needed for at least 3-months for corms to develop. Leaf foliage for the crop can grow in as little as 2 weeks after planting if receiving consistent rain. Planting corms on time was a difficult task for many farmers. After the initial rainfall, it is important to plant all field crops immediately and a hierarchy is established. The most necessary crops for farmers are planted first and lesser crops are planted after. Some of the responses that were collected by farmers from interviews were that planting corms after the first rainfall was challenging since other major field crops also need to be planted right after the rains in order to increase their chances of completing a growth cycle. Rainfall across the Kaffrine region is limited and water serves as one of the most important elements impacting crop growth and yield. The significance of planting taro during the onset of the first major rains represents a broader issue facing farmers in the region since climate change is bound to make this situation worse in the future. Climate change will affect the quantity and reliability of rain plus result in higher temperatures that will affect all crop production. Taro would have the advantage of providing food in drought situations when other crops fail. One future strategy would be to look at the possibility of rain harvesting and using this water to protect crops and taro from failure in the form of a lifesaving irrigation.

5.2 Familiarity and Sources of Farmer Knowledge of Orphan Crops

The results indicate that most farmers are highly familiar with crops that have been deemed internationally as "lost crops" (Worldwatch Institute, 2011). Globally crops like Pearl Millet, Bambara Groundnut, African Rice, Fonio, and Bitter Tomato are unknown in Europe and North America. However, the general notion of "lost" or "neglected" crops supports a narrative of being underutilized in only certain parts of the world. In the local context of communities in Senegal, these lost crops are commonly used in a variety of cuisines and intercropping systems. For instance, farmers were familiar with most of the crops shown to them and many of the farmers grew these crops. Millet and sorghum are common field crops in Kaffrine because of their relatively good yields for a semi–arid environment. All farmers had experience growing these old grains. Bitter tomato is locally called *jaxatu* and is a common vegetable in Senegalese dishes such as *Maafe* and *Thieboudienne.* Farmers that were familiar with all the crops mentioned some other crops not listed that are not regionally grown in Kaffrine because there is not enough annual rain, this was especially true for African Rice, which all farmers were familiar with, but did not have experience growing. Most farmers recognize crops like taro, Bambara groundnut, and air potato as forage crops. These crops are acknowledged as wild and have a perception closely tied to poverty. The general perception of taro and other minor crops are as poverty crops presents larger challenges for their adoption.

When it comes to the sources of farmers' knowledge regarding orphan crops, it was shown in the results section that most farmers are very familiar with minor crops as forage crops. One of the leading influences leading to farmers' negative perception of

taro is their sources of knowledge. A majority of farmers learn about orphan crops from other ethnic groups or through inter-regional travel. Ethnic groups in Senegal that cultivate taro are minorities and are viewed with lower esteem than the Wolof majority. The undesirable view of ethnic minorities such as the Pulaar perpetuates a notion that their agricultural practices and crop selection choices are backwards. Taro is associated with ethnic minorities and poverty. Farmers outside of ethnic minority groups perceive taro, fonio, and air potato as lesser crops and associate them with the poor. The perception is ingrained in how farmers acquire information about underutilized crops. Modern sources of agricultural technical knowledge are often viewed as being disseminated by Senegal's Department of Agriculture, extension officers, or agricultural research institutions and are more important. Knowledge is determined by the institutional backing from major agricultural research entities and impacts farmers' crop selection. Lesser-known crops are commonly viewed as being for the poor or even worse as primitive. The National Academy of Sciences published a book entitled "Underexploited Tropical Plants with Promising Economic Value," where it states, "most agricultural scientists are unaware of the scope and potential offered by tropical botany. The discipline suffers largely because the major centers of scientific research are located in temperate zones. There is an urgent need for plant researchers to become acquainted with tropical plant life. Important new products – such as oils, gums and waxes for industry; proteins for food and feed; and chemicals for pest control - are likely to result from their attention. Agricultural departments and major agricultural research institutions inherently impact what farmers decide to grow. The lack of promotion of underutilized crops by respectable research institutions functions as criteria that prevents broader

adoption by rural farmers that are already aware of their potential" (National Academy of Sciences, 1975).

Farmers in Crop Diversification with Taro Project by Gender

Women in agriculture function as an important aspect to the agricultural labor market. However, despite being a major component of the agricultural work force they receive less access to land, financial resources, inputs, and extension services when compared to male farmers. The lack of female farmers involved in extension projects and re-adoption programs of underutilized crops comes at a great cost. Women are primarily responsible for preparing food for their household. One of the reoccurring barriers that prevents taro from being adopted by farmers was not knowing how to properly prepare taro in common Senegalese meals. There is a division between crops that are grown for relative value and crops that are grown for dietary necessities.

Women function as the bridge between agriculture and nutrition; women are often the sole caretaker and responsible for feeding different age groups in a household. Incorporating more female farmers was one of the considerations that was overlooked when selecting the 15 farmers in the Crop Diversification with Taro project. Farmers that were selected to participate in the project were hand selected by the village chief, however, there should have been higher numbers of women in place to uphold an equal representation of male and female farmers. Across the agricultural work force, women are also involved in gathering food and post–harvest during farm activities.

The role of women as conservationists of underutilized and neglected crops is directly tied to re-introduction efforts of taro root. Across Senegal, especially noted

amongst the Peul Fuuta and Jahanke ethnic groups, taro is known as a women's crop. In Bayliss- Smith's (2012) work, "Taro, turmeric and gender" (2012) he states, "the same gendering of production and use applies to taro, especially Colocasia taro… the skillful and arduous work of production is very largely the domain of women." Bayliss- Smith's (2012) observations are steeped in the Polynesian context, but the relevance to the agricultural gender division of taro in Senegal are similar. In Kédougou, women are the primary growers of taro. The crop is viewed as being associated with the stomach and has said to be related to women. Furthermore, during all observations where taro was sold as a street food or snack, woman were the vendors selling boiled taro. During the collection of field research in Kédougou many male heads of households detailed that their wives usually grow taro for the household and cook it alongside other food items. In many ways targeting female farmers is a pathway to re-introduce crops that hold potential to increase food security and household levels of nutrition.

C. Follow-Up Research 2017

Taro is a minor crop in Senegal even though it is cultivated by small ethnic groups in the southern region. In theory, growing alternative crops that can fill any production need sounds like the perfect solution, however, many factors continue to impact farmers decisions to adopt alternative crops that help them increase food security. According to farmers, the primary reason why they continued taro adoption included many factors. At the same time, reasons for dis-adopting the crop were also varied. The section below discusses conversations and feedback to explain why farmers adopted or dis-adopted the crop.

Low-Inputs

Farmers that participated in the Crop Diversification with Taro project were recommended to use compost, manure, or peanut shell mulch to better prepare the soil before planting. Taro farming can rely on locally available residues, which reduces the cost associated with growing the crop. The growing material can be shared and collected through vegetative corm production. This aspect of taro production enables farmers with the opportunity to act as stewards and breeders. An adopter of taro in 2015 commented on how convenient it is to save the planting material of taro, which makes it easy for intercropping schemes. Accessibility of vegetative material before re-introduction of the crop was limited in southern Senegal. Farmers that have adopted the crop function as regional resources to share plant material. Nutrition is an outcome of the food system and the nutritional benefits of taro by farmers were reported to be useful as a side meal or include in stews as dark greens when the leaves are used. After 2015, another adopter commented that it is good to have something different in our meals; we usually eat the same foods day after day. Diversifying with taro root has also doubled a way to enhance the diets of rural people.

Livestock Fodder

Many household resources go into maintaining healthy animals for their farming systems. Raising animals and feeding them is expensive; the cost to keep livestock comes directly out of farmers' restricted resources. Much of the organic waste and left over agricultural products are given to livestock – an important decision since the same products are encouraged to go into compost to help increase soil fertility. The outcome is a competition between feeding animals and feeding the soil. One of the primary benefits

for growing taro by farmers was it being used as livestock feed. Taro corms can provide energy in the form of carbohydrate for humans, but its long cooking time to remove calcium oxalate crystals reduces its popularity. This issue related to calcium oxalate crystals, also exists when using it as a feed to animals and the only way to remove them is through a high-energy processing of the corms. Feed grains are the most common food for animals along with forages. Processed taro by products such as taro flour or ground taro corm meal can also be used to feed domestic livestock. Across the Pacific, the silage process has been used to feed pigs. Culturally pigs are not appropriate for Senegal because of their religion, however adopters did use cooked taro leaves to feed to their chickens. Other researchers such as Melese Temesgen have said that "taro feed can replace expensive cereals and less available agro-industrial by-products with unconventional sources of raw materials, that are less exploited. This is one of the solutions to reduce cost of production and contribute to increased supply of animal protein to rich and poor people's" (Temesgen et al., 2017). Many farmers reported using a form of taro leaf meal after it had been dried or cooked to feed their chickens. Although the full extent of how much taro corms, leaves, or stems are appropriate to feed animals, it was reported as one of leading reasons why they continued to grow taro.

Food Security

Taro's utilization as a crop can be harvested for its roots or leaves is what farmers have reported as a key benefit. Adopters reported that harvesting taro leaves early did not impact the tuber production. Although taro production was recommended to integrate as a field crop, adopters continued to use it as a small homestead garden crop. The idea of using kitchen garden crops as a pathway to increase food security and nutrition for rural

farmers is not a new idea. Plants grown close to living quarters offer a higher potential to be used in meals. Taro grown in gardens is an accessible way to harvest leafy greens for children and the elderly. It can also provide shade when planted with other crops in a mixed cropping garden system. It is common that field crops grown by the head of household are given to them individually since men often eat meals separately from the rest of the family. Adopters reported the corms being difficult to eat, however the leaves, which contain many valuable minerals and vitamins, were said to be useful for children and can be used to secure increase household nutrition.

Salinity Levels Tolerant

Kaolack and Kaffrine regions in Senegal have an excess of salt in their soils. Saline soil intrusion impacts agricultural production and impact what kind of vegetables can be grown. One of the common statements made by adopters was taro's ability to do better than most crops in saline soils. Soil salinity reduces most other crops' yields. Another benefit of taro that influenced farmers' adoption was the ability of taro to grow reasonably well even with poor soils. One adopter noted that they did not have to do anything besides the initial planting and the crop still produced impressive yields.

Pest Management

Farmers reported few diseases and pest problems when adopting taro. An adopter mentioned that it could be grown in live fencing gaps since grazing animals don't chew it. Even when other plants nearby underwent pest attacks taro remained unbothered. Most farmers viewed its resistance to pests as a positive.

Dis-Adoption of Taro

Different challenges have impacted farmers' decisions to dis-adopt taro after it was extended in 2015. Overall, its' association with ethnic minorities and connotation as a poor person's crop was amongst the leading factor causing farmers to stop growing it. External factors such as labor constraints and weed management were also noted as barriers preventing continued adoption.

Ethnic Minority and Poverty Association

When following up with farmers in 2017, one of the main points repeated by non-adopters was taro's association with the Peul Fuuta. The details of this ethnic group are noted in the Literature Review. The Peul Fuuta community is often viewed as originating from Guinea and migrating into Senegal. Fula people or *Pulaars* are a nomadic ethnic minority and inhabit many different countries across West Africa. Although this ethnic group is small it constitutes 23% of the population in Senegal. The Wolof majority makes up 43% (ANSD, 2020). This information is useful to understand the context of dis-adoption because many the two ethnic groups above have a complex relationship. The two ethnic groups rely on different forms of livelihoods. Pulaars are known as nomadic herders that travel with their animals to follow rains across Senegal and even other Western African countries. Wolofs are sedentary farmers that depend on rainfed agriculture. These two contrasting livelihoods have been a point of conflict since pastoralism depends on the same land as the sedentary agriculturalist. Violent conflicts over what is forageable, grazing land have made ethnic relations tense. During the Follow-Up research visit in 2017, many farmers stated their decision to dis-adopt taro

was because it was known as a Pulaar crop. As Purseglove (1972) mentioned in his book, "taro is a basic subsistence plant" (Purseglove, 1972). Its reputation as a wild crop that is sometimes cultivated, but still undomesticated has made some farmers believe that it is forage crop used by people in deep poverty. Cultural preferences and identity of what people consume and cultivate is a theme across all agricultural societies. For instance, when conducting follow-up interviews with a dis-adopter they commented that Wolof people eat millet and rice, Pulaars eat taro. The cultural significance of taro as a sign of socio-national identity was not initially considered as a major factor to prevent adoption. As recent as December 2020, Peter Joseph Matthews and Michael Edmond Ghanem (2020) developed a research paper discussing the negative feedback loops that maintain the orphan status of certain crops. Their research explains the negative perception and social biases that contribute to taro's status as a neglected crop. The association with taro as a poverty crop in addition to how little taro is supported by governments and agricultural institutions perpetuates its status as an orphan crop and serves as a primary cause for not growing it.

Calcium Oxalate Crystals and Cook Time

One of the key benefits of taro's ability to grow fully without the threat of pest is the presence of calcium oxalate crystals in the leaf and tubers. When taro tubers are uncooked, they act as an irritant and can cause the mouth to swell. This calcium oxalate irritant property can only be removed from corms by cooking them. When doing follow up visits to farmers' fields in 2017 they described the calcium oxalate crystals by pointing to their teeth and saying "itchy". Some farmers mentioned that taro has a reputation that its corms feel like eating rocks. Purseglove (1972) mentioned this aspect about taro

calcium oxalates in his Tropical Monocotyledons book, stating, “some taro cultivars contain unpleasant amounts of calcium oxalate crystals that must be removed during cooking. The corms must be roasted, baked, or boiled” (Purseglove ,1972). One factor that was commonly cited was the long cook time required to boil down taro to an edible form. For many rural households in Guennte gouye cooking takes resources like fire wood from the bush and charcoal in order to cook and boil food. These are precious resources for families and many of the farmers that stopped growing taro described this as a barrier since the corms must be boiled before eating.

Farmer Knowledge

As an introduced crop, many farmers were unaware of how to best use taro corms and leaves in their everyday meals. The leaves are similar to spinach and other researchers have reported that it is commonly used as” tropical spinach.” Dis-adopters claimed that one of the factors for not growing taro was not enough knowledge on how to use it in meals. Referring back to the case studies, Momadau Cisse, a dis-adopter in 2016, mentioned this as one of the factors why he did not continue to grow taro in 2017. Momadau’s main crops were peanuts and maize. Peanuts in Senegal have been included in local cuisine and are often utilized in many different meals, whereas taro is being re-introduced to Senegalese cooking is being reinvented into local cuisine.

Age and Behavior Change

The majority of the farmers involved in the Crop Diversification with Taro project were in the age group of 35- 44 years. The average life expectancy in Senegal is 68 (World Bank, 2018). Most farmers involved in the project are considered middle aged,

which has benefits since this age group makes the chief decisions in their household and choose what to grow each season. There is an opportunity for this age group to support the rest of their family by adopting taro and diversifying their diets. This age group was the most valuable since many of the farmers were young enough to be flexible with adopting new ideas. Younger farmers on average owned less land than older farmers. Young farmers with small amounts of land were hesitant to use valuable space to grow a new crop they were unsure about.

The average farm size by hectares and age demonstrates a trend that older farmers tend to have more farmland. Another point to keep in mind is that the sample size was small and only a few farmers were in the younger age groups. The oldest farmer to participate in the study was 70 and had the most farmland. The oldest farmer didn't want to adopt taro and he didn't see the point of growing something that only a few people eat and is not well known.

Behavior change research for incorporating new agricultural techniques has long claimed that younger farmers are more likely to adopt new crops and techniques. Byron Zamasiya (2017) conducted a recent research project that took place in Zimbabwe studying the factors influencing behavioral change among smallholder farmers towards adaption to climate change. They found that age was a factor that impacted attitudes on behavioral change toward climate adaption. Younger farmers were more willing to adapt to climate change than older farmers. Age and behavioral change studies related to adoption of agricultural techniques has been a growing area in agricultural research.

Labor and Poor Infrastructure for Marketing

Taro is a crop that is easy to grow. One of the major barriers after taro is harvested is its processing. Labor and poor Infrastructure for selling taro was cited by over half of the dis-adopters as a leading factor for not adopting it. Many farmers expressed that once the tubers are uprooted the skin of the corms has to be peeled – this process is labor intensive and takes a lot of time. When considering cost benefits, some farmers believe the cost associated with spending time peeling and cooking the corms makes it not worth cultivating. The labor trade off was also mentioned during growing taro after it is initially planted. Many dis-adopters also cited weeding as a factor that played a role in their decision to dis-adopt. Weeding is labor intensive and labor is a limited resource. Various dis-adopters cited that their family members are their primary source agricultural labor and they have to be selective about where their time is used when managing each crop.

D. Ethnobotanical Research on Taro in Senegal

Preferred Crops and Ranking

Across Senegal, different ecological zones impact what farmers can grow, however it does not impact the preferences for what they would ideally like to grow. Africa is the origin point for many crops including okra, pearl millet, sorghum, finger millet, African rice, and teff (Technical Centre for Agricultural and Rural Co-operation, 2015). Based on the findings of the preferred crops ranking survey despite being urban or rural, farmers consistently ranked maize as the most preferred crop. Maize was ranked as 5, the most preferred crop in all locations, and to better understand this preference for maize, it is important to grasp the broader shift towards maize production by farmers in

Senegal. Maize has surpassed several traditional cereals like sorghum, millet, and African rice. According to previous research on the production of cereals crops on the continent of Africa, maize is produced more than any other of the major cereal grains. Table 2.5 shows the production rates of maize. What can be concerning about this trend is that maize is a crop native to the Americas and many farmers in Senegal struggle to provide enough nitrogen for maize crops to obtain reasonable yields. The overall shift to maize production on the continent of Africa can be tied to maize's relative value on the global market. Maize can be used in a variety of commercially viable ways, for instance, ethanol, livestock feed, and human consumption. The emergence of maize serves as an indicator to further push taro and other underutilized crops to the periphery. Based on the findings from the preferred crop rankings, all signs point in the direction that farmers will continue to depend on cereal grains and more precisely ones that garner the most international support. Maize research for farmers in eastern and southern Africa where maize consumption is the highest has sustained support by agricultural researchers to develop improved varieties of maize that are stress tolerant and more nutritious. Maize is outpacing many traditional crops on how it is utilized in Senegal. This poses many potential challenges for farmers since maize requires many inputs such as nitrogen to grow productively. In addition, farmers report having higher post-harvest losses with maize due to poor storages practices. The emergence of maize as a highly preferred crop by farmers in different regions of Senegal is representative of its dominance and consistent high ranking amongst farmers in the survey. So, what can be done about underutilized crops and what is their role in cropping systems now that maize is preferred? Taro and other underutilize crops will certainly not replace major crops like

rice and maize. Their potential thrives in their function as a supplementary, buffer crop to complement low yields of major food crops. Intercropping taro and maize was noticed across many farmers' fields in Kédougou, their physiology is similar whereas maize has tillers and taro has petioles, they grow at a similar rate and with proper spacing can function as cultivating plots that are useful for domestic consumption and selling for profit.

6. Recommendations

Tropical root crops still face many challenges that limit their ability to help rural communities attain better nutrition and increased levels of food security. In recent decades, other root crops such as cassava, sweet potatoes, and yams have garnered much support. Biofortified sweet potato has now been developed to address Vitamin A deficiency for children under the age of five across eastern and southern Africa (IFPRI, 2006). Unlike other root and tuber crops just mentioned, taro is still under-researched. The factors contributing to taro's status as an underutilized crop will be highlighted in this section and offer recommendations to increase its visibility as a practical food source.

A. Research Knowledge

There is limited information on taro. Current research is often disparate and conflicting, consisting of information that mixes cultivars. In addition, the several names for taro function as a consistent point of confusion when identifying the crop. Local names are used more than categorizing it under the scientific or general name taro. This has made collecting information on the crop difficult. Research is scattered and often inaccurate. Many cultivars of taro exist, and each has different traits. The polymorphic nature of the root crop makes it easy to adapt and thrive to local ecologies. An important shift that must occur to enhance the utilization of taro is for international agricultural research intuitions to research and document its usage. What is needed is comprehensive documentation on taro's agronomic traits, biology, morphology, taxonomic classification, and nutrition. Research is also required locally

and regionally to detail the unique traits of the crop's cultivars that have emerged in rural communities. There is a need for agricultural research institutions to invest in the study of taro as an alternative, diversifying crop.

B. Plant Breeding

The genetic diversity of tropical root crops is extensive. The vegetative aspect for replicating taro makes its genetic material abundant , but also very difficult to breed. Traditional taro farmers have participated in plant breeding and conservation by selecting out traits they desire through domestication. Agricultural research breeding programs tend to focus on major crops to improve traits for worldwide consumption. Improving taro through plant breeding can accelerate its utilization around the world. One of the takeaways from this research project was identifying what traits farmers like about taro. Barriers such as long cook time and presence of the irritant property, calcium oxalate crystals prevent farmers from adopting taro. The support of plant breeding would be monumental to help analyze the genetic diversity and select materials that would make taro easier to utilize by farmers around the world, especially varieties with low levels of calcium oxalate.

C. Incorporating Taro in Consumption Habits

Cookbooks for crops that are orphaned are commonly used as a strategy to mainstream their utilization. One of the main factors that cause farmers to dis-adopt taro was not knowing how to incorporate it into meals. A recommendation that can be employed to increase the usage of taro is promoting its leaves as tropical spinach. It is

difficult for tropical environments to produce dark greens such as kale, spinach, Swiss chard etc. The rate of diabetes has skyrocketed in Senegal due to the overconsumption of rice. Many are reconsidering the emphasis on rice in Senegalese cuisine. Pierre Thiam, a Senegalese chief, and fonio enthusiast, has promoted the usage of fonio as a nutritious, climate-smart alternative to rice. Fonio is a member of the millet family. Thiam has created new recipes to promote the consumption of fonio. Similarly, taro has the same potential to be reinvented and incorporated into contemporary Senegalese diets. As a pan-tropical crop, taro has already been used in diverse ways in many different cultures around the world. In West Africa, taro leaves are most commonly cooked into stews. Purseglove (1972) has written that the young shoots are blanched and eaten like asparagus. In Trinidad, taro leaves are chopped up and boiled with okra, ham, and crab (Purseglove, 1972). Most Americans are familiar with taro as a flavor for bubble tea - there are even greater opportunities to use taro in North America and Europe by using it as flour. This can help generate income for low-income countries by growing taro and processing the product to be exported as flour. As the world population increases, the importance of diversifying agriculture and diets becomes ever more pressing.

D. Agricultural Policy

Governments and national agricultural policies influence what farmers cultivate. In Senegal, many challenges exist for smallholders to achieve food security and crop diversification. Government support consists of providing farmers with agricultural input subsides that help them increase their peanut and maize yields. Changes in the national agricultural policy should include supplying agricultural extension workers

with information and resources on how to best grow taro in Senegal. Government spending in Senegal is allocated overwhelmingly to input subsidies and funding self–sufficiency programs paying farmers to grow rice. Data shows that despite funding these sectors, Senegal will still depend on rice imports for national food security (Matsumoto-Izadifar, 2008). Moreover, developing a pathway to encourage farmers to grow traditional crops is a recommendation that could be in the form of providing seed material and large-scale media promotion of crops like taro. A large-scale media campaign for promoting the benefits of orphan crops could encourage farmers to adopt them. A national campaign could also dispel negative associations of the underutilized crop with poverty. Furthermore, cash incentives for growing underutilized crops can help break barriers and encourage behavior change of hesitant farmers.

E. Kitchen Gardens

Kitchen gardens are a vital aspect of overall household food security. Traditional taro farmers in southern Senegal commonly feature taro in small plots close to their homes, managed by women. The crop's proximity to homes makes it easier to infuse into casual meals and increases its likelihood for utilization. In the results section, a photo, Figure 2.4, shows a rare look at highland taro in the Fouta Djallon. Taro has a long history of being cultivated in kitchen gardens and can be promoted as such to other farmers across Senegal. Small homestead taro gardens with mixed cropping can function as an example that can address multiple issues such as increasing food availability and using limited amounts of land. Using kitchen gardens encourages the ability for taro to be grown in a mixed intercropping system with other nutritious

crops such as okra, hot pepper, and bitter tomato. Field crop schemes are often farmed on many hectares of land far from the home. Kitchen gardens are developed next to walkways close to living quarters. They also can function as a way to promote crop diversity since gardens are displayed in front of their home or the backyard for all of the community, which encourages others to grow their own nutritious and diverse plots. In addition, taro gardens can assist reducing poverty by acting as a supplemental food source to limit the amount of income being spent on market-bought food items.

F. Livestock Feed

Animal feed is often collected from food scraps and feed livestock. Food scraps are also considered a key component of compost. Some farmers reported feeding their livestock maize or market-bought feed that gives their animals enough nutrition to lactate and produce eggs. One of the benefits of adopting taro reported by farmers was its ability to be used to feed animals. The most common livestock maintained by farmers in Guennte gouye were goats and chickens. The discussion section reflected on the findings of how farmers utilized taro leaves to feed their animals. Taro has the potential to be used as an animal feed. More research is needed to understand to what extent corms and leaves can support the dietary needs of animals, however, farmers that participated in the Crop Diversification 2015 project have already found it to be useful. Imported animal feeds are often too expensive. Producing animal feed locally with taro offers opportunities for farmers to generate income selling animal products or the ability to upscale their livestock management system by feeding more animals.

7. Conclusion

The primary purpose of this research paper was to evaluate factors that influence farmers to adopt or dis-adopt taro root as an alternative field crop. This paper also set out to document the presence of taro root in Senegal, and explore the potential of its utilization as an alternative, rainy season field crop that can act as a buffer against starvation. Subsistence crops are grown for household consumption and do not have an aim to be sold in markets and are often grown in kitchen gardens. Across the world, taro has been used to improve the nutrition and food security of rural people.

Understanding the factors that influence farmers to adopt or dis-adopt taro is crucial to identify what structures are needed to assist its cultivation and utilization in Senegal. This research project also documented the already existing taro practices amongst populations in southern Senegal that have a long tradition of growing the crop. Examining the previous literature on taro was also important to analyze what other researchers have said. It was found that taro's market potential and industrial processing are developed in some parts of the world such as Asia and the Pacific. West Africa, on the other hand, has more land growing taro compared to the Asia-Pacific region, but limited resources allocated for taro production.

This research found that most farmers are familiar with orphan crops like taro, however, the heavy association with these crops as poverty foods combined with ethnic minorities provides a bias against taro from being grown by Wolof farmers. The promotion of rice and maize by the national agricultural sector has made many farmers concentrate all their resources on growing these crops. The emergence of maize has overtaken traditional crops and it should be noted that - climate change, land degradation,

and population growth in West Africa will make achieving food security ever more challenging in future years.

As food shortages and droughts become more frequent, it could not be more apparent that diversifying with taro and ther under-utilized crops is needed now. The benefits of taro highlighted in this paper focus on the agricultural and nutritional merits of the crop, however, there are also many medicinal properties this plant has to offer. Institutional research support is needed to help identify and outline accurate information on the crop. Indigenous crops were commonly featured in cropping systems before colonial administrative control. After Senegal's independence, many colonial agricultural policies continued to focus on groundnut production for export. Government management over the agricultural sector in Senegal has the potential to now change and encourage farmers to grow traditional crops by providing them with the resources they need to increase their cultivation of taro. Lastly, plant-breeding opportunities can help improve traits and increase characteristics preferred by farmers. Other research has stressed the importance of improving crops based on farmer-centric preferences. Farmers' involvement in plant breeding is essential to promote taro's usage. This research details traits farmers would like to see in taro to make it easier for them to cultivate and could be use to help plant breeding program reduce undesirable traits like calcium oxalates crystals. Lastly, ongoing support is necessary to train farmers on emerging, new sustainable agriculture technologies so they can benefit from the merits of practicing restorative agriculture.

Taro is just one of the many orphan crops that have high potential, but continue to been under-researched. The relatively low–inputs and ability for taro to be grown on

marginal land are key attributes for farmers with limited capital. There is certainly already momentum pulling humankind and science to consider more plant species that are environmentally less exhaustive. This research is a testament to that change.

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