Vol. 17(2), pp. 302-309, February, 2021
DOI: 10.5897/AJAR2018.13815
Article Number: 78E000966072
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Traditional solar salt production in Lower Casamance (Senegal): Environmental and socio-economic benefits and disadvantages

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Received 17 December, 2018; Accepted 7 February, 2020

To produce salt, women in Lower Casamance (southern Senegal) traditionally practice artisanal fire salt-farming (AFS) by heating a brine with a biofuel (mangrove wood). The thermal energy produced favors the evaporation of water, the saline concentration and the precipitation of crystallized salts. In recent years, artisanal solar salt-farming (ASS) has been introduced in the region using the thermal energy provided by the sun. The purpose of this paper is (i) to compare the two salt-farming techniques; (ii) to present the advantages and disadvantages of ASS in terms of impacts on the environment and the socio-economic activity of local populations. Six AFS villages (Marakissa, Diafar Duma, Diaghour, Souda, Boucotte and Cabrousse) were selected and female salt-farmers were trained at the ASS in Guinea-Bissau. In 2015 and 2016, salt production by ASS was sufficiently abundant for domestic needs to be met and salt excess trade to be possible in the local market. In conclusion, the ASS can advantageously replace the AFS for domestic use. The sale of solar salt locally or even regionally remains to be proven. A critical analysis of the ASS in terms of sustainability and a serious market study of the "salt" sector will be necessary to consider such a perspective.

Key words: Solar salt-farming, benefits, disadvantages, Lower Casamance, Senegal.

INTRODUCTION

Common salt (Halite-NaCl) is an important economic mineral that is widely distributed on all continents and occurs in large reserves. It is among the five major chemicals which forms the backbone of the chemical industry including petroleum (Feldman, 2005; Affam and Asamoah, 2011). It plays a critical role in the chloro-alkali industry and is used for both animals and humans in their diets (Livingston, 2005). World salt production, dominated

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by China and the United States, was 264 million tonnes in 2013. There is almost no salt production in the entire Central and West African region except in Ghana and Senegal. These two countries meet the requirements of most of the region (Mannar and Yusufali, 2013). Senegal remains the Africa’s foremost salt producer with more than 450,000 tonnes a year (Lagnane, 2012). Although its share of world production is small (less than 1%), it does contribute quite significantly to the generation of extra income for both rural and urban inhabitants through production, collection, transport and export operations (Kanouté et al., 2018).

Two kinds of salt are produced in Senegal: the Industrial or modern salt on large scale and the Artisanal or traditional salt, on small scale. Nearly, 90 percent of the salt exported is produced by industrial units. The National Saloum Salt Company (SNSS), leader in the sector with 120 000 tons per year alone accounts for about 35% of this production and SELSINE with 10 000 tons per year (3%) occupies the second national place. The remaining 62% is divided between small, informal producers located on Pink Lake (38 000 tonnes a year and 10 percent of the national production in average), the Fatick region, the Kaolack region, the Saint-Louis region (Malan, 2015) and the Casamance region. Artisanal salt production is the only method practiced in Casamance. It includes the artisanal fire salt-farming (AFS) and the artisanal solar salt-farming (ASS) (Grdr, 2017).

The artisanal fire salt-farming technique (AFS)

Traditional salt-farming is called artisanal fire salt-farming (AFS). It consists in heating a brine with a biofuel (mangrove wood), the thermal energy produced favoring the evaporation of water, the salt concentration and the precipitation of crystallized salts. It is a seasonal activity practiced by women during the dry period, between February and April. Its implementation is proving very painful for people and a major consumer of fuel that must be drawn from mangrove forests. The salt produced is mainly reserved for the self-consumption of family farms. In addition, the local demand for salt has not stopped increasing since the 1960s, particularly because of population growth and the development of processing units (fish products, tanneries, production of African Locust beans etc.). The salt of Casamance is very far from satisfying the demand. Technically, the production of fire salt consists of three main series of operations: salty land harvesting, brine preparation (salty-saturated water) and brine heating (Delbos, 2008).

(i) The salty land is harvested in the scraping areas, surfaces of coastal or alluvial marshes, more or less large, devoid of tree vegetation and resulting from a more or less old process of tannification (zones of "tannes", non-flooded and over-salted surfaces). In Guinea, it results from the clearing to satisfy the need for firewood or the abandonment of diked rice fields.

(ii) Brine is prepared by putting the salty land in filter containers, desalting them by adding fresh or marine water and collecting the brine by gravity. In Benin, the containers, called “bous”, are large braided baskets with mangrove stems. In Guinea, they are called “tankés”, which are cones more or less flared and formed of a structure of mangrove wood and a braiding of palms (Geslin, 2008).

(iii) The brines are heated with a fire powered by wood. In Benin, enamel basins of about twenty liters are filled with brine. They are placed on a clay oven of rounded or oblong shape and of variable size. In Guinean mangrove, panis are used, rectangular metal trays of 100-120 cm long, about 60 cm wide and with edges about ten centimeters high. In Casamance and Guinea-Bissau (Kapatres region), cooking trays are steel sheets made by local blacksmiths. The dimensions are 0.80 m x 0.80 m for a height of 7 to 10 cm. The cooking tray is placed on a hearth of clay fueled with firewood. A cooking tray is used for one or two seasons.

Detailed operations of AFS include scraping and storing salty land at the sites, on-site installation of production equipment (filters and brine tanks), firewood supply (before the start of the first salt productions and then as needed), the filtration of salty land for obtaining brine, the heating of brines, the on-site dripping of salt produced, transport in basins and bags, individual storage at the level of concessions. Whatever the method used, brine heating requires a permanent presence around the hearths to skim the brines, avoid salt crusting on the bottom of the containers, maintain a high heat, remove the salt and refill the containers (Delbos, 2008).

The artisanal solar salt-farming technique (ASS)

The International Solidarity Associations, Grdr Migration-Citizenship-Development (Research and Realization Group for Rural Development in the Third World) and Univers-Sel, as well as the Senegalese partner Regional Framework for Rural Dialogue (RFRD) proposed an alternative to develop salt production in Casamance. This is the artisanal solar salt-farming (ASS) that uses the thermal energy provided by the sun to evaporate a small blade of salty water spread on plastic sheeting. This alternative technique was first disseminated in Benin and Guinea, with the support of salt marsh farmers in Brittany, the salt marshmen gathered in Univers-Sel. It is based on the same principle of concentrating a brine by evaporation. As with the AFS, the brine is prepared from the same raw material, the salty land that is harvested from the scraping areas. The same tools and methods for brine preparation in “bous” or “tankés” are used. The single change remains that the heating of the brine with

Figure 1. Location map of the research-action area.

wood is replaced by a natural heating, the sun, whose drying effects are reinforced by the wind action. The brine is distributed in small basins in clay, crystallizers. Thanks to the combined effects of the sun and the wind, which depend on the local climate, the water evaporates and the salt crystallizes. Salt is collected and often mixed with fine clay particles.

In recent years, an artificial support, such as a plastic sheeting for ASS production, has been promoted in Guinea (2010), Guinea-Bissau (2012) and Senegal-Casamance (2014) by Univers-Sel (Figure 3). The brine is collected under a filter consisting of an empty bag (braided palm leaf, fabric ...) which is attached to stakes (minimum 4 stakes). The salty land, which has been harvested from the scraping areas, is deposited inside. Water is poured on the surface and passes through the salt-water filter. The brine collected is then spread on crystallizers consisting of black plastic sheets of 5 m x 2 m and a recommended thickness of 250 microns. Sheetings are placed on flattened, leveled, ventilated surfaces and located out of the risk of flooding and contamination. The small thickness of brine accelerates its concentration and the large evaporation surface of the crystallizer increases the salt production. Harvesting usually occurs before the end of the day. It will be noted that it is possible to act on the size of the grains of crystallized salt. Coarse grains are obtained by slightly stirring the brine during the crystallization phase (Figure 6). Thus, the innovation brought by ASS technique to Casamance is the use of plastic sheeting as crystallizers. The harvested salt is supposed to be cleaner and its color whiter because it has fewer impurities.

Between 2014 and 2016, a research-action project was carried out as part of the implementation of the Citizen Governance Program for Coastal Ecosystems (CGPCE) to introduce this new technique and demonstrate its feasibility in Casamance. The purpose of this paper is to (i) present the results of this research action; in order to (ii) show the advantages and disadvantages of ASS in terms of impacts on the environment and the socio-economic activity of local populations.

MATERIALS AND METHODS

The three years of research-action have led to the development of three main activities. Initially, it was a question of defining a situation of reference or to make an inventory of the practices of salt-farming in Casamance. Six AFS villages (Marakissa, Diafar Douma, Diaghour, Souda, Boucotte, and Cabrousse) were selected by Univers-Sel (Figure 1). The census of the production sites, the profile of the female salt farmers, the main technical itineraries, the salt production chains, the constraints and strategies of circumvention were identified.

(i) Then, in March 2015, a cultural exchange trip was organized at Kapatres in Guinea-Bissau, where Univers-Sel had previously initiated a similar research-action. The purpose of the trip was to familiarize 11 Casamance women and a RFRD facilitator with the ASS technique.

(ii) The effective implementation of the research-action project began in April 2015 with the recruitment of female volunteers provided with plastic sheeting and useful tools. They were

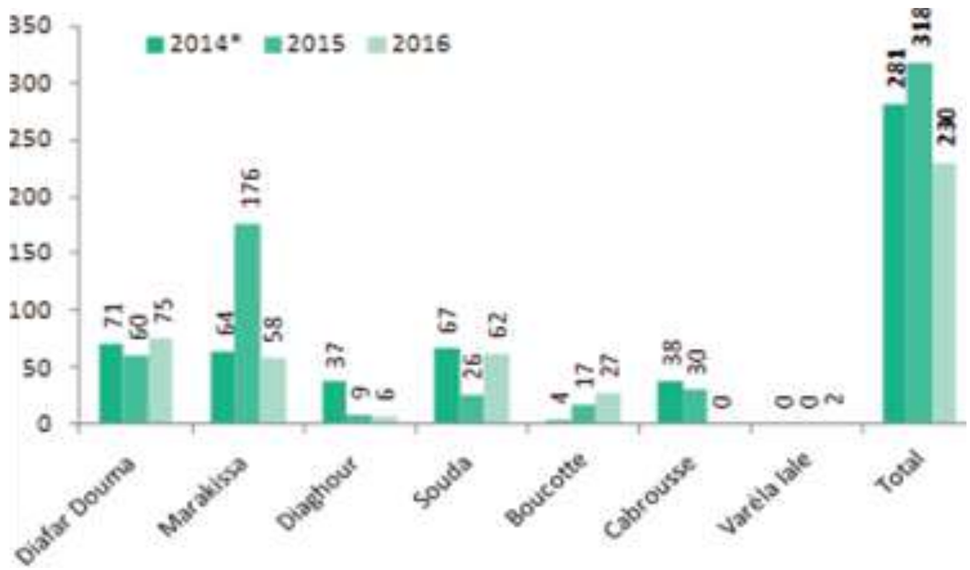

Figure 2. Evolution of involved women salt-farmers between 2014 and 2016.
Source: Grdr (2017).

accompanied daily in their salt harvest campaigns by the RFRD facilitator.

(iii) In June 2016, the RFRD led to a thinking of salt marketing strategies during a forum that brought together the women salt-farmers from the different sites involved in the project. The results of the project were presented and discussed during the prospective workshops organized in the pilot territories.

(iv) The assessment of the solar salt quality produced was carried out by sampling salt at the various project sites. The samples were analyzed in the laboratory of the Chemistry Department of Assane Seck University of Ziguinchor (ASUZ).

(v) The environmental and socio-economic impacts were thereafter assessed through data analysis (production quantity and costs, family incomes, purchasing power…) and qualitative household surveys (social stability, well-being, poverty decrease…) in the targeted villages.

RESULTS

Evolution of the production and the women salt-farmers

All the 281 women salt-farmers initially engaged the research-action practiced AFS. They gained a solid experience with regard to salt-production techniques. In 2015, during the first ASS campaign, 318 producers adopted the ASS technique and produced 68 891 kg of solar salt. During the 2016 campaign, they were 230 and produced 54 925 kg of solar salt. The growing interest in ASS was confirmed in 2016: the number of women salt-farmers increased in the villages of Diafar, Souda and Boucotte, and women from Varela Lale (in Guinea-Bissau) were involved. The experiment attracted 131 new producers from the 7 villages. In addition, women practicing AFS came from neighboring villages (Bemet Bidjini, Fanda, Kamoya, Silinkine and Koumbamo) to learn more about the ASS technique.

Nevertheless, some producers have abandoned it and, finally, the number of women salt-farmers decreased between 2015 and 2016. This is mainly caused by difficulties linked to storage and marketing the production of the 2015 campaign, particularly in the village of Marakissa where an important abandon rate was recorded (118 women) (Figure 2).

Reduction of production costs

From an economic point of view, the ASS can generate significant revenue with the reduction of production costs, the marketing of salt produced and the improvement of individual productivity of work. The results of the research-action show that the production costs of ASS are four times lower than those of the AFS: 200 F CFA kg^{-1} against 875 F CFA kg^{-1} (Figure 3). Labor productivity, which is greatly improved, makes it possible to satisfy domestic needs (self-consumption) and generate marketable surpluses. For example, during the 2016 campaign, the average production per female salt-farmer was 240 kg of salt with a free margin of 50 F CFA kg^{-1}. We can therefore estimate an average net income of around 12,000 F CFA (240 kg x 50 F CFA).

Wood exportation

The research-action showed that the consumption of wood resources for ASS has decreased in the pilot villages. In fact, unlike the AFS, a major consumer of wood, the ASS no longer exerts any pressure on wood

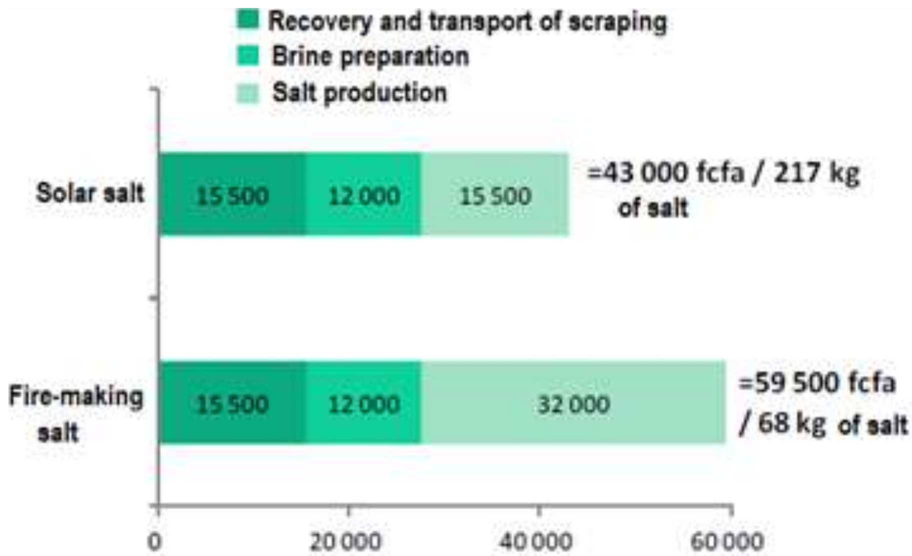

Figure 3. Comparison of the production costs per campaign between ASS and AFS.
Source: Grdr (2017).

resources which, in some localities, is very strong. Univers-Sel has estimated that the production of one tonne of fire salt requires about three tons of wood. In 2014, nearly 60 tonnes of wood were used for salt production in the six villages. Based on the initial production of salt in 2014, the Grdr determined that in three production seasons, the switch to the ASS has saved 180 tonnes (60 x 3) of wood and avoided the clearing of several hectares of forest, mainly the mangrove.

DISCUSSION

The benefits and strengths of ASS

The development of the salty lands of Lower Casamance in southern Senegal is a long-standing concern of the populations (Bouju, 1994) who have adapted to harsh pedoclimatic conditions, particularly since the drought of the 1970s. The sustainable management of the mangrove and associated salty lands require the control of the exploitation of forest, water and biological resources to produce biofuels (firewood), materials (timber) and foodstuffs (rice, wildfowl, shellfish, crustaceans, fish, salt etc). Finding an alternative that eliminates the use of wood in salt production is the major challenge faced by ASS precursors who have shown both environmental and socio-economic benefits.

Environmental benefits

The ASS provides many environmental benefits, such as combating deforestation, preserving biodiversity, regenerating natural ecosystems and reducing harmful gas emissions. In the mangrove zone, the Univers-Sel experiment in Benin and Guinea has established that the solar alternative contributes to the reconstitution of mangrove forests. In Benin, for example, with respect to the ecosystem of the exploited zone, AFS activities are destructive of the environment, particularly the mangrove, because of the excessive use of wood for cooking brine (Dossou, 2000) (Figure 4). While mangrove swamps occupied the entire coastline from east to west about 5000 years ago, it now only extends to the western sector, showing currently strong physiognomy and floristic indigence (Toffi, 2008; Toffi and Akoègninou, 2008; Toffi, 2010).

Mangrove, which is among the most productive forest in the world, provides many services to local populations (aquaculture, fishing, hunting, natural sanitation, coastal stabilization, tourism). At the global level, it contributes to the storage of atmospheric carbon. The forest benefit is not negligible in a context of natural resource management and climate change. Another less significant environmental impact is the reduction of CO_2 pollution, the main greenhouse gas and Cl_2, chlorine gas, causing pulmonary degradations when inhaled (Figure 5).

Socio-economic benefits

The reduction of production costs, the improvement of labor productivity, the household food security, the better health of the population, the reduction of working time, the reduction of the hardness of work are all economic and social benefits of the ASS technique. From a social

Figure 4. Supply of firewood for brine heating in AFS process.
Source: Univers-Sel, DESASORO Project, Guinea-Bissau, (2014).

Figure 5. Hard sanitary conditions in AFS process (inhalation of chlorine vapors).
Source: Univers-Sel, DESASORO Project, Guinea-Bissau (2014).

point of view, the ASS has a positive impact on household food security in the concerned villages. Salt production is secure because there is no longer the risk of firewood lack. Higher incomes lead to higher purchasing power, lower poverty, and greater social stability. Moreover, the reduction or complete elimination of harmful gases inhaled (carbon dioxide, chlorine ...) has greatly improved the health and well-being of the populations. In addition, ASS has significantly reduced the working time. While the AFS requires a continuous presence of approximately 8 h per day for fire maintenance, the ASS requires only a maximum of 2 h of work per day. While the 2015 campaign did not identify the real-time gain, it was noted during the 2016 campaign that some women used the time released to intensify vegetable production (better watering) or search for wood for the kitchen. Other surveyed women have used their time for socio-cultural activities. Saving time also allows women salt-farmers to develop income-generating activities, such as gardening, fruit orchard or the small trade of garden and fruit produces. The production of solar salt has also reduced the hardness of work. In fact, if the preliminary steps, such as scraping and transporting the salty land, remain unchanged and difficult, the solar evaporation of the brine avoids the unpleasant effects of the heat and fumes released by the burning of firewood.

Disadvantages and weaknesses of ASS

Environmental disadvantages

The solar salt production chain ranges from scraping salty soil to picking up the finished product, going through salvaging the brine, concentrating it and spreading it over the plastic sheeting (Figure 6). At the end of the three years of research-action, the general observation remains that improvements are needed at each stage of the chain. The possible improvements relate in particular to the hygiene and sanitary measures which suffer from a lack of control and rigorous follow-up. This explains the reluctance of some traders and local consumers with regard to the solar salt of Casamance. The brine is taken in a medium often in contact with bacteria and other pathogens (open air). Also, the quality of the plastic sheets, serving as a support for the brine, deserves special attention. The probable chemical contaminations induced by the effect of solar rays on the plastic material must be evaluated and discussed. The durability of the waterproof properties of plastic subjected to aggressive conditions (sun, brine) is znot known and their fate after use

Figure 6. ASS production process.
Source: UNIVERS-SEL and ADAM (2010) In Camara N. and Lamine M., 2010. Rehabilitation of traditional rice fields. Solar salt production. Final Report salt component. Programme for sustainable development of mangrove production in marine Guinea, 114 p.

(recycling, destruction, landfill) is even less.

Socio-economic disadvantages

The desire to market the salt produced faces several obstacles. Storage must be efficient in the long term. Some consumers consider the Casamance ASS unfit for consumption. There is national competition with the salt of Sine-Saloum, a priori of better quality.

In fact, the quality of salt does not meet the health standards applicable in Senegal and worldwide, including the iodine content (Lagnane, 2012). The importance of iodine in human health is well documented. Zimmermann (2007) and Vasudevan et al. (2018) explained that iodine deficiency (ID) causes a broad range of adverse effects on health resulting from the inadequate production of thyroid hormones that are collectively termed ID disorders (IDD). An ID during pregnancy increases the risk of spontaneous abortion, low birth weight and infant mortality as well as raising the risk of neuromotor behavioural and cognitive impairment in the offspring. Knowles et al. (2018) demonstrated, in a study conducted in India, Ghana and Senegal, that Iodine deficiency is the world's most prevalent cause of preventable brain damage. The most severe, visible, forms of the deficiency are now rare due to prevention through Universal Salt Iodization (USI), which is accepted as a highly cost-effective public health strategy.

In Senegal, iodine issue is a real concern with regular surveys and a considerable body of literature regarding this topic. There is a national-level quality control mechanism run by the Domestic Trade Service in collaboration with other control bodies such as the customs service, the police and health services. Staff have been trained and provided with iodine testers (Kanouté et al., 2018). Menon and Skeaff (2016) recommended, for this reason, the use of iodized salt for populations inhabiting endemically iodine deficient regions. Spohrer et al. (2015) propose, for example, the use of bouillon seasoning, a widely consumed source of salt, for USI effectiveness in West Africa.

Also, the regular supply of quality sheeting (at least 250 microns thick) requires an additional cost related to transport from a remote manufacturing location (Dakar). The durability of sheetings subject to desiccation and their fate after use are also crucial issues. The problem of the commercialization of the solar salt of Casamance can also be explained by the fact that the women salt-farmers do not know the realities of the market and the marketing circuits. The lack of organization of salt producers is also an obstacle to the sustainability of the activity. Better support would allow them to gradually adopt the innovations induced by the ASS.

CONCLUSION AND PERSPECTIVES

The research-action has shown that the ASS has more advantages than the AFS: time saving, less arduous tasks, lower loads through the substitution of wood, no pressure on wood resources. In the targeted villages, the use of salt is mainly domestic for the consumption of the populations and the conservation of the food.

The surplus salt produced means that the female salt-farmers perceive the salt-framing as a potentially income-generating activity. However, it remains to prove that the solar salt produced is marketable locally or even regionally. Several obstacles present themselves: the ignorance of the laws of the economic market by women salt-farmers; direct competition with salt from the Sine-Saloum region cheap and iodized. Salt iodization remains a major obstacle to marketing because health standards impose it in Senegal, Guinea-Bissau, and worldwide, including in coastal areas where iodine deficiency is rare.

Non-iodized salt produced in excess could be used for the industrial processing of agricultural and fishery products (salting), but the volumes produced should correspond to the demand. The RFRD wishes to sustain the research-action by continuing to offer support to women salt-farmers, particularly at the organizational and commercial level as well as for the conservation and distribution of salt. A critical analysis of the ASS in terms of sustainability and a serious market study of the "salt" sector will be necessary to consider such a marketing perspective.

ABBREVIATION

AFS, Artisanal fire salt-farming; **ASS,** artisanal solar salt-farming; **Grdr,** Migration-Citizenship-Development (Research and Realization Group for Rural Development in the Third World); **RFRD,** Regional Framework for Rural Dialogue (Conseil National de Concertation des Ruraux, CRCR, in French); **CO_2,** Carbon dioxide; **USI,** Universal Salt Iodization; **ID,** iodine deficiency; **IDD,** Iodine deficiency disorders.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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