Yield Gap Assessment in Senegal and Senegal River Valley: Factors affecting the yield gap and postharvest activities impact on its improvement

Abstract

Senegalese agriculture relies mainly on seasonal production activities marked with low productivity. This contributes to high dependency on imports as far as food self-sufficiency is concerned. This dependency on cereal imports, primarily of rice, wheat and maize has increased gradually due to their low incentive to produce comparison with cash crops (e.g., peanut and cotton), inappropriate policies and failures in improving agricultural productivity. Domestic agricultural production of cereals in Senegal covers approximately 40% of the country's demand. And it is characterized by a low level of fertilizer application and low accessibility of inputs such as seeds and fertilizer. Reflecting these obstacles, the dependency of rice and maize on imports in Senegal reaches up to 80% and 50%, respectively.

At the country level, the gap between current and potential yield is estimated to be 49.75% and 79.75% for rice and maize production, respectively. But in the Senegal River Valley, these yield gaps are less severe; they are 37.9% and 58.8% respectively. These yield gaps are caused by biophysical, socio-economic and institutional factors. Among them, problems associated with harvest and postharvest hindrances need to be addressed. And, as domestic financial support for loosening up these constraints is not easy because of a lack of financial capacity of government and farmers, one must look for financial support from overseas. Without funding from outside, many governmental agricultural projects targeting to boost up domestic agricultural production are under danger of failure.

Keywords: Yield Gap, Senegal River Valley, Factors Affecting the Yield Gap, Productivity

1. Introduction

Cereals have been the most important food resources in the world for human and livestock consumption. Whatever happens in the cereal sector therefore will have a strong bearing on the global food supply.

There is a growing demand for cereals, both in developed and developing countries which has created a need and exerted pressure for yield improvement. According to FAO, "World Agriculture: Towards 2015/2030", improvement of cereals yield account for about 70 percent in production increase in industrialized countries. Thereby, the expansion of cultivation area in production increase represents just one-quarter of the increase in production in those countries. However, in developing countries where land availability and low productivity are widely observed the production increase is hugely related to area expansion accounting for a larger share. This concern is particularly relevant in many developing countries in Africa, where expansion of area has contributed about 35 percent of the increase in production. For Latin America its accounts for 46 percent of production increase in 2002 (World Bank). Furthermore, as reflected by Malthus's theory, as food and energy demands are raising exponentially due to the exponential increase of population and an arithmetic evolution trend of natural resources, yield improvement becomes never than before crucial to overcome current and future pressure on food demand due to the increase of the global population as well as an increase of food consumption with income growth (Lobell, Cassman and Field, 2009).

Yield gaps can be used as a parameter for measuring agricultural production performance at different levels: locally, nationally, subregionally, continentally or more widely. The concept of yield gaps originated from studies conducted in the 1970s by IRRI (International Rice Research Institute) (MOMDAL, 2011). A study of FAO, in 2004 showed that most of maize and rice varieties fail to attain their potential yields at the farm gates around the world and mainly in developing countries. In the world, actual yields account for only 4 to 6 tons/ha compared to a potential yield of 10 tons/ha to 12 ton/ha for rice farming. In Senegal like most developing countries, this concern of low yield needs to be highlighted. Senegal's yield gap for rice since 1961 as actual yield has been

increased from 1.1 ton/ha to 4.1 tons/ha. But for the maize, this is not the case as actual yield was stagnant at 0.8 tons/ha from 961 to 1979 (FAO). And from 1980, the actual yield of maize has slightly increased to about 1.3 ton/ha with an exception of 2.3 ton/ha, 2.7 ton/ha and 2.8
ton/ha in 2003, 2004 and 2004 respectively due to a special program of maize launched in 2003.

In Senegal, the yield gap which is the difference between the potential yield and farmers' average yields can be attributable to many factors such as inefficient farming practices, socioeconomic constraints, and poor organic traits of local varieties (Traoré et.al, 2010). Commonly, potential yield can be defined as the level of the yield of an adopted crop variety or hybrid grown under the most favorable conditions without any constraints, limitations from water, nutrients, pests, diseases and others necessary factors of production (Assane Beye, 2021; PRACAS II). Thus, it can be identified in research stations (JICA, 2014). Notice that, yield level varies with the level of improvement of varieties and/or local conditions related to agricultural production due to nontransferable environmental characteristics (Feed the Future, Senegal, January 2018).

1.1 Motivation

Normally Senegal should not be so dependent on rice and maize imports because of its huge comparative advantages (environmental and human resources advantages) in the production of rice and maize. Among them there is the sun exposure, land availability of 3.8 million arable hectares with 2.5 million hectares cultivated (MEF (Ministry of Economy and Finance), May 2008), water availability of 4,192 sq Km (water surface) and Senegal River Valley as well as Anambé Basin suitable to double cropping with annual water availability (development of irrigated crops) (ANSD, 2024).

1.2 Purpose

Given the importance of cereal crops in Senegalese dietary habits, the purpose of this study is to investigate rice and maize sectors in Senegal for a possible future self-sufficiency. The main objective of this investigation is to analyze the performance of domestic rice and maize production and their improvement factors. This analysis will rely on current Senegal's as well as Senegal River Valley's rice and maize yield gap exploration and factors that affected yield gap.

1.3 Literature review

Rice and maize production i.e. in general cereals have been forgotten many years in scientists' researches and economics literature (OFS, 2010). And demand satisfaction relied on extensive farming using unimproved local seed varieties which led to nonsustainable ~~gricultural~~ production (FAO and WARDA 2004-2005 report). Furthermore, water scarcity and extensive livestock created in West Africa few plant availability and wondering desertification which increases productivity randomness because of locusts and insects attacks (WARDA 2004-2005 report; PARMH2, Jume 2023). In that context, the Africa Rice Centre in collaboration with JICA launched the NERICA (New Rice for Africa) variety (short-term variety) and cultivable even in the most harsh, complex rice ecologies (JICA, 2006). In Senegal, this initiative named Participatory Varietal Selection led to the creation of fifteen short-cycle new varieties (Africa Rice, 2009) to achieve rice self-sufficiency, as well as food security through improved domestic production (JICA, 2019).

1.4Methodology

The methodology of analysis of this subject is based on the model of yield gap assessment and management by using farmers' average yield and potential yield notions to evaluate the improvement of agricultural production. The yield gap is analyzed by using ISRA 2011 official potential yields meaning, rice and maize agricultural results in Senegal and in Senegal River Valley.

1.5 Data

At the country level, data are from FAO and from SAED, ISRA and ANSD for Senegal River Valley. The yield gap is analyzed by using a time series data starting from 1993 to 2022.

Result and discussion

2. The assessment of yield gap

2.1 Evolution of rice and maize yield

Rice and maize are respectively the first and third world-dominant food crops and they are important strategic instruments in many countries for their national economic growth (De Datta and Singh, Nain, Hansra & Raina, 2011). Thus, many countries and mainly developed countries are struggling to overcome agricultural production constraints for progressive sustainable and efficient agricultural production.

In Senegal, the importance of millet/sorghum in grain production is not negligible and represents on average 57% of total grain production since 2009 despite the increase of rice and maize production and consumption. However, the production of millet and/or sorghum showed a slow rate of improvement over the period between 1995 and 2009 (an average of 1% per year compare to an annual average of 3% for rice and maize) due to a very small increase of yield during that period (Ndiaye and Niang, 2010). This situation can be explicated by a low level of the annual average growth rate of domestic cereal production (1.4% per year, ANSD, 2020; DAPSA, EAA, 2020-2021). Ended, that rate is lower than the one of the population growth rate (2.56%). Together, this contributes to the decrease of per capita domestic production of cereal.

2.1.1 Rice and maize production in Senegal

Basically, in Senegal, rice farming was under rain fed and recession in Casamance (southern part of Senegal), in the Northern part of the country and in certain Center pockets. These areas have a long tradition in rice production and consumption. For many years, the Southern part of Senegal, Casamance areas was considered to be the country's granary. However, since 1980, policymakers and agriculture specialists' specialists in agriculture unanimously agreed that the Northern part of the country, more precisely along the Senegal River Valley, is the main area of Senegal to achieve self-sufficiency in food. This is because after the 1980s' frequent drought events that had affected much-irrigated agriculture, many strategies and projects were implemented to boost agricultural production in Senegal River Valley (PSE I).

Except Casamance area, millet was traditionally the main produced cereal in Senegal. But, the rapid development of groundnut farming, in the aftermath of the Second World War resulted in the shrinking of cultivated area in millet (Senegalese Agriculture Direction). This decline of millet farming promoted an important as well as massive rice importation policy in order to satisfy the growing demand in cereals of Senegalese. With rapid urbanization and the decline of the domestic production of millet outpaced by cash crop such as groundnut and cotton, rice became an important provision in Senegalese diet According to its advantages agricultural production, Casamance, the southern part of Senegal, excellent yields and volume of production in maize should be attained. And can be reconverted to cash crop product because of its huge domestic demand (PRACAS I).

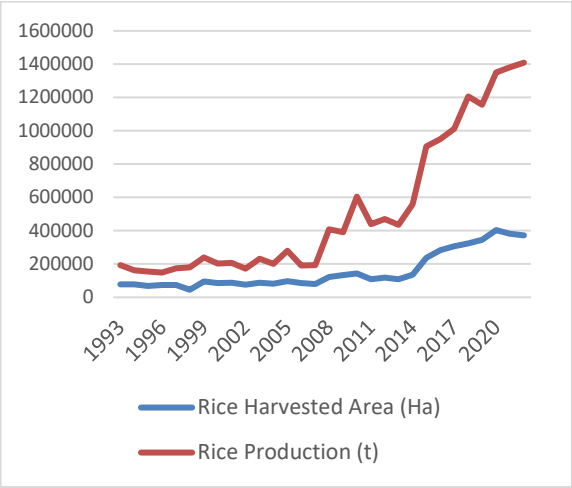
The total production of Senegal River Valley area in maize, which is manly an irrigated maize, does not exceed 10% of the total national area of cultivated maize. The production of maize in Senegal has varied in saw-tooth with a relatively constant growth rate from 1961 to 1990. During the period 1991-2000 (FAO) it decreased slightly. And the main factors of constraint that restrict the production of maize in the country are:

1 Drought and poor soil fertility,
2 The lack of adapted varieties to the soil and climatic conditions, 3 The problems of plant protection,
4 Outdated equipment (depreciation) and
5 Lack of appropriate, efficient techniques of production and if they exist their accessibility to farmers.

Given the expected returns of the environment and early local varieties yielding up to 1 ton/ha, seed were improved to highly selected composites or synthetic varieties with a potential yield of 2 ton/ha to 4 ton/ha by ISRA in 1996. The use of hybrid maize seed is justified by a real willingness of intensive maize cropping system as well as the achievement of yields higher than 5 ton/ha (ISRA 2009).

Since its introduction in Senegal, maize was and is still cultivated as around compound crop in many areas. And it is often sold at the roadside by women who grill it with charcoal fire. This green maize commercialization is becoming increasingly important in urban cities. This green maize trading occupies and attracts new actors such as men, young and old villagers. Maize is nevertheless increasingly used as semolina couscous or desserts. And is frequently cultivated in a small part of the garden where women plant some plants for extra income and diverse meals. Its productivity is currently low due to the poor quality of local and unimproved cultivars. Due to that, ears are relatively small. But the future promises a great expansion of maize with varieties particularly favorable to the country's environment. Currently, maize is mainly cultivated in Senegal River Valley, in Sine-Saloum and in Casamance. However, during the rainy season maize farming extends throughout the national territory. If in Senegal rice production growth is related to area expansion rather than yield improvement, for the maize, extensive agriculture was not even able to enhance the national production.

Figure 1. Trends of rice production and harvested area



Source: FAO, 2023

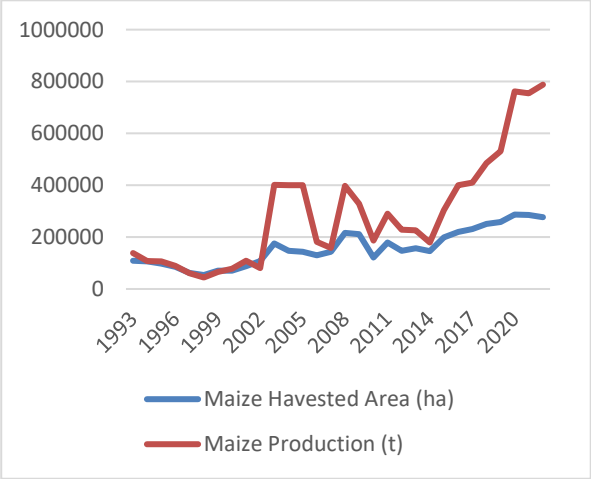
From 1993 to 2011, the rice sector registered approximately a production and land use growth rate of 1.9% and 4.7% respectively. Nonetheless, yield growth rate is lower than the production one. We can see that the annual domestic production of rice was relatively below 200 000 tons per year before 1999 and greater between 1999 and 2007. And since 2008 financial crisis, production increased more considerably. This increase of rice production can be attributed to the Grand Offensive for Agricultural and Food Abundance program (GOANA) launched in 2008 to boost efficiently cereal production. This improvement of production is obviously related to agriculture intensification because harvested land decreased by 3.4% from 2008 to 2011 with a production growth rate of 2.4%.

Nationally, in the maize sector, production and harvested area growth rates from 1993 to 2011 are respectively around 4.2% and 2.8% respectively. The production curve of maize has a decreasing trend shape. But from 1993 to 2001, the domestic production of maize increases slightly. Nonetheless, this increase remained lower than the immediate past years giving hereby a V shape production trend from 1993 to 2001. And according to the nature of maize, high level of requirement in fertilizers, the shortage of the domestic production can be correlated to soil exhaustion after many years of exploitation without or less organic input incorporation (enrichment). At that period, farmers focused mostly on the expansion of marginal land as evidenced by a 1.4% growth rate in harvested area compared to only 0.85% increase in production.

However, in 2002, the production increased considerably. This period coincided with the revival program of maize launched by the government and the sell/contracts program between producers and industries which motivated farmers more in maize production. These programs gave better incentives to farmers and financial institutions to encourage many producers to produce maize. That program boosted nationally the maize sector by incentivizing and encouraging many producers' willingness in maize farming. For that, maize yield approximated in 2003 and 2005 the rice one's and out passed it in 2004. Unfortunately, this progression was just for a while because four years after even though maize yields were little bit improved, the annual gap between its homologue, the rice, varies between 1.3% and 2.5%.

The growth rate of yields in rice and maize production, 2% and 1.4% respectively, between 1993 and 2011 exhibited the country's weakness in satisfying its local demand for cereals, rice and maize. Thus, there is a long way as well as many obstacles to strive to match the production of rice and maize with 2.56% population and 46.8% urbanization growth rate (ANSD, 2011). However, from 2015 to 2022 productivity increased considerably because of many agricultural policies (PRACAS II).

Figure 2. Trends of maize production and harvested area

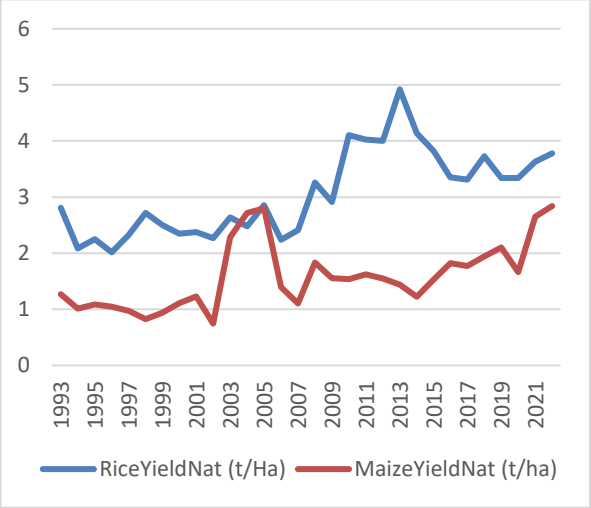


Source: FAO, 2023

The drastic decrease of the domestic production of Senegal in maize between 2006 and 2007 coincided with REVA event program. At that period the government incited people (retired workers, young, women ...) in cereal production, mainly rice, maize,

millet, cowpea and cassava. However, input distribution and financial resources accessibility were hugely criticized by agricultural actors. Many of them sought that facilities were distributed to new comers without any experience in agricultural production named "Sunday farmers" (les agriculteurs de Dimanche). And most of them focused on green maize production (grilled and market a cross roads) at a small scale.

Figure 3. The yield difference between rice and maize



Source: FAO, 2023

2.1.2 Rice and maize production in Senegal River Valley:

The Senegal River Valley is a unique, specific and strategic irrigated agricultural area in the country. The recession of the River flooding in river basins allows local residents to make a dry season crop farming on alluvial soil. Then, the River

Recession allows them to practice double crop production during the dry season, complementary to the rain fed one.

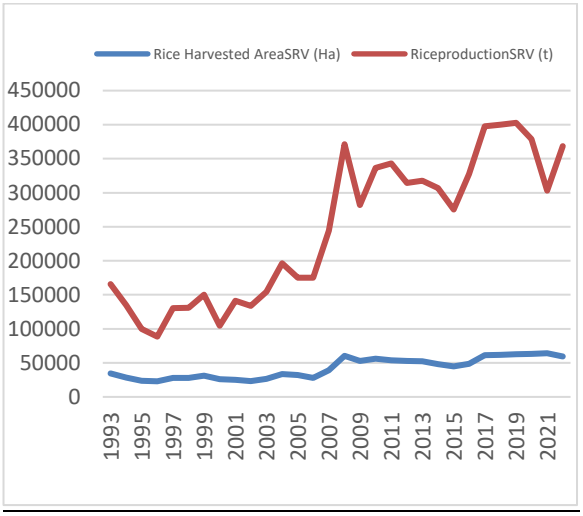
The first improved hydro-agricultural layouts made in the Senegal River Valley (SRV) were implemented during the colonial period in the fifties years with stated objectives of diversified food self-sufficiency. Due to that, the government was heavily involved in the entire sector of production until the middle of ninety years. Since that time, the government started to withdraw gradually from the collection and the distribution of different agricultural products. But it continued structuring facilities, especially in the Senegal River Valley and to support producers. Indeed, Senegalese authorities relied heavily on this area to increase agricultural production and satisfy local demand for some potential below reasons that give the region the greatest possibilities of high output:

1 Surface water availability, 2 Quality of hydro-agricultural layouts and 3 Farmers' expertise.

The development of Diama and Manantali dams which regulate the annual fluctuation flow of the river improved gradually rainfed and recession farming through irrigated agricultural. Irrigated agriculture offered a good potential to improve cereal productivity mainly in rice and maize farming in the Delta River and the Middle Valley. The degradation of the environment due to ecological changes, the increasing salinity of irrigated land in the delta, wind erosion and the intensification of rice production by the misuse of inputs (fertilizers, pesticides) as well as land issues are the major constraints of the development of agricultural production in SRV. The SRV is trying now to diversify its production efficiency to secure the domestic demand. And in this strategy of agricultural product diversification, rice and maize are the main targeted cereal production due to their huge increasing share on imports.

Contrarily to the national domestic production where rice production increase is mostly related to area expansion, in Senegal River Valley the performance of rice farming is mainly due to agriculture intensification. From 1993 to 2011, a 2.45% increase rate of used land raised the production growth rate to 4.11%. This is due to agriculture intensification in SRV but also to its semi-agribusiness aspect which was implemented in the valley since sixty years ago. For that, even though basic norm in fertilizers were not used, the quantity used was and is still better than in other areas exploited mostly for consumption, and subsistence agriculture. Furthermore, soil is less poor compared to other places where soil fertility is decreasing drastically due to lack of organic or fertilizers incorporation.

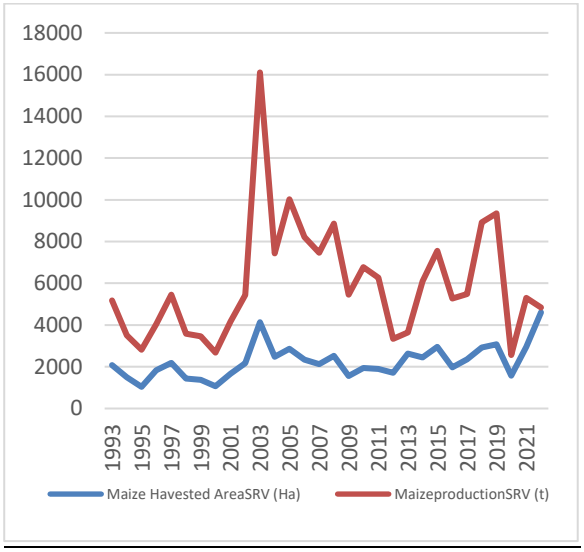
Figure 4. Rice production and harvested area in SRV



Source: SAED & ANSD, 2023

The growth rate of rice production in SRV (4.11%) is nearly close to the national one (4.66). That closeness shows the importance of this zone in rice production which secures 70% of this staple local demand (ANSD). Like in rice, maize production in SRV is more intensive than the national one's. But it intensification is lower than the rice one's. Nonetheless, this observation is not so surprising because maize was not traditionally cultivated in this zone. Its principal area of production is the Southern, central and eastern parts of the country since a very long time ago. During the period 1993-2011 harvested area decreased by 0.51% with about 1.1% increase in production. The maize program was also very productive in SRV in 2003 with a pick level of production of 16104 tons of maize.

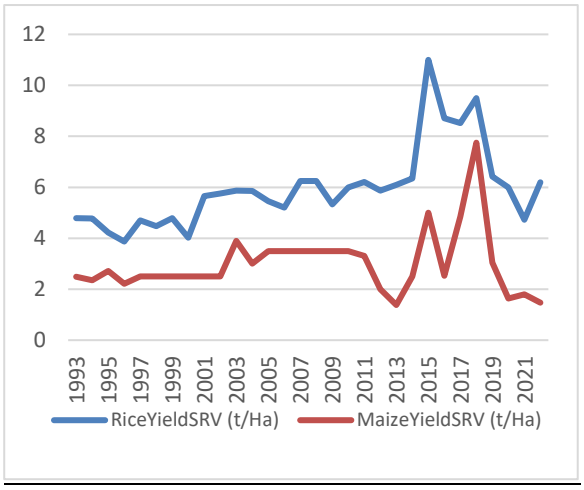
Figure 5. Trends of maize production and harvested area in SRV



Source: SAED & ANSD, 2023

Regarding rice and maize yield trends from 1993 to 2011, we can see that productivity (yield) is almost relatively constant. Then, the maize program and GOANA program were not even able to change remarkably the structure of productivity difference in SRV. This is due to farmers' efficiency, skill of agricultural production and organization under cooperative (for mutual social and financial support between them) but also to the fact that the government furnishes almost the necessary heavy (expensive) facilities in the River (layouts, improved hydro-agricultural infrastructures).

Figure 6. The yield difference between rice and maize in SRV



Source: SAED & ANSD, 2023

2.2 Analysis of current yield gap

Generally existing varieties have a potential yield much higher than their actual yield on a farm . This difference on a farm in yield is particularly observed in modern and hybrid varieties. There is considerable variation in the actual achieved level of yield even under a similar production system because of climatic factor variability and its randomness (FAO, 2004). This difference exists even in potential yield which varies according to the location of the research station and the growing season (Traore et.al, 2010).

In Senegal from 1993 to 2011 rice yield fluctuated only between 2 ton/ha and 4.1 ton/ha, while the potential yield of modern and hybrid varieties is about 8 ton/ha to 12 ton/ha. However, in SRV farmers' average yield is between 3.87 ton/ha and 6.25 ton/ha while 4.02 ton/ha to 5.96 ton/ha and 4.02 ton/ha to 7.58 ton/ha for the rain-fed season and the irrigated rice respectively. For the maize, we have a yield of 0.74 ton/ha to 2.71 ton/ha and 2.35 ton/ha to 3.9 ton/ha respectively at the national level and in Senegal River Valley zone. Contrarily to the rice, the irrigated and rain fed farmers' average yield of maize in SRV are almost the same. These yield differences among farmers in the same zone are frequently observed because of farmers' different levels of skill in crop management as well as other socio-economic conditions. Furthermore, progressive (professional) farmers usually obtain higher yields and more profits than ordinary farmers because of their knowledge and willingness in rice or maize production. However, attention should be given to ordinary farmers according to the number of people under their charges (Seck et.al, 2010). Indeed, family farming death will create more labor for the agri-business but generated revenues will not be able to cover their needs of consumption as when they were cultivated their own farms.

Generally, the yield gap between the potential yield and farmers' average yield ranges from 10% to 60% (FAO, 2008). And the yield gap concern is more persistent in rain fed, flooding (for the rice) and in "problem soil ecologies" (FAO, 2008) areas which tend to be the less exploitable in terms of yield gap narrowing.

2.2.1 Definitions

The yield gap also known as practical yield gap is the difference between the potential yield and farmers' average yield over some specified spatial and temporal scale of interest. It has been widely used in literature in the past two decades (Ittersum, 1997) and its definition is hugely related to the potential yield measurement.

2.2.1.1 Potential yield

The potential yield or the maximum attainable yield is the yield of experimental plots of an adapted variety of crop or hybrid which is grown under favorable physical conditions without any growth limitations from water, nutrients, pests as well as diseases and with the best–known management of practices at a given time in a given ecology system (Evans, 1993 and FAO, 2008). The potential yield is determined by three factors which are solar radiation, temperature and water supply for any given site and growing season (Traore et.al, 2010 and Lobell, 2009). As the three environmental factors vary throughout the year, the potential yield will depend on the location as well as also on the crop sowing date and the maturity rating (Seck et.al, 2010).

The potential yield is usually used in irrigated systems because the crop can be grown under an adequate water supply throughout its growth period. Therefore, there is another expression used for the maximum possible yield under rain fed named water-limited potential yield (IRRI) because "most rain fed crop suffer at least short-term water deficits at some point during its growing stage (Lobell, 2009) due to the rain randomness and its unequal distribution. The water limited potential yield itself is the yield of an adopted or hybrid variety grown under rain fed in a favorable condition without any growth limitations from nutrients, pests, or diseases.

Sometimes the maximum farmers' yield can also be used as a proxy potential yield value. That alternative potential yield estimation is to observe the maximum yield achieved among a sizeable sample of farmers in the zone of interest (Sadras et.al, 2002) which satisfies all standard norms on production factors.

2.2.1.2 Farmers' average yield

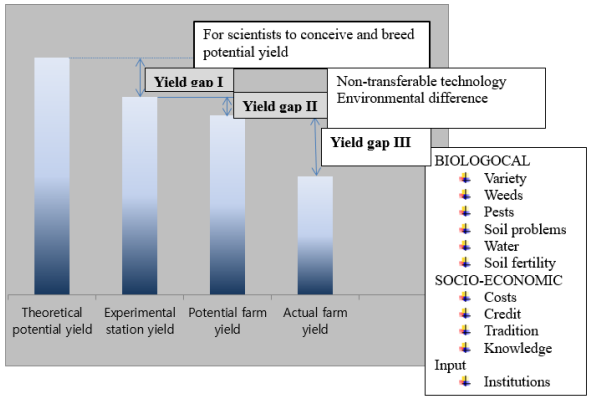
The farm-level yield or farmers' average yield is the average of farmers' yield in a given targeted area at a given time in a given ecology. It varies from one locality to another and depends on environmental factors but also on farmers' skill and their socio-economic conditions.

2.2.2 The yield gap components

The yield gap can be subdivided into three components (Figure 7). The first yield gap, Gap I, is the

gap between the theoretical potential yield and the station experimental yield for which scientists conceive and breed varieties such as super rice or maize.

The second component, Gap II, is the difference between the experimental station yield and the potential farm yield. That gap is caused generally by not transferable factors such as environmental conditions and some of the built-in component technologies which are available only at the station of research (Africa Rice, 2008). Therefore, it is very difficult to narrow this yield gap and it is often not economically exploitable. However, the accumulated knowledge by farmers and the availability of innovative technology helped to reduce this gap in



Source: De Datta, 1981

Figure 7. Yield Gap components

several countries, more concretely in advanced and industrialized countries.

The third component, Gap III is the gap between the potential farm yield and the actual farm yield and is mainly caused by differences in the management of practices. Usually, farmers do not use adequate doses of input and recommended agricultural practices for many socio-economic factors. Contrarily to other yield gaps, this last one is manageable and can be narrowed by increasing efforts in research and by the transmission of innovative practices to farmers at real-time as well as by an appropriate intervention of the government (particularly in institutional issues) in agriculture development.

2.2.3 Yield gaps of crop in Senegal

A yield gap exists in Senegal among different crops. In rice and maize farming, the Direction (Office) of Agriculture stipulated that their potential yield is due to the fact that the Sahelian zone is highly favorable to cereal farming, more particularly under irrigated systems (Dingkuhn and Sow, 1995) with a potential yield from 8 ton/ha to 13 ton/ha for rice.

The frequent varieties of rice exploited in SRV area are the Sahel 108, Sahel 201 and Sahel 202. In the rest of the country, governments are struggling to encourage farmers to use new improved varieties such as, mainly, the NERICA ones which are highly adapted to harsh production zones.

The average yield of farmers in rice and maize in Senegal (SRV) are 4.02 ton/ha and 1.62 ton/ha (6.21 ton/ha and 3.3 ton/ha) respectively. However, the potential yield under better management is 8 ton/ha (8 ton/ha and 10 ton/ha). The yield gap in percentage (37.9% and 58.75%) confirms again the importance of SRV zone in Senegal in the achievement of self-sufficiency.

Table 1. Yields and Yield Gap

Yield level and Yield Gap (ton/ha)		SENEGAL	SRV
Potential yield	RICE	8	10
	MAIZE	8	8
Farmers' average yield	RICE	4.02	6.21
	MAIZE	1.62	3.3
Yield gap	RICE	3.98	3.79
	MAIZE	6.38	4.7
Yield gap (%)	RICE	49.75	37.9
	MAIZE	79.75	58.75

Source: FAO, DA, ISRA and SAED, 2022

The national yield gap in rice and maize production which are 49.75% and 79.75% of potential yield is due to the huge environmental difference inside the country and by other socio-economic constraints of production. These socio-economic factors contributed highly to output stagnation and decline in Senegal.

2.3 Factors affecting yield gap

The achievement of food security and the struggling against poverty are the major challenges that Senegal needs to address. However, their realizations are mainly constrained by:

1 Weak agricultural productivity,
2 Climate changes,
3 The degradation of monetary income
4 High growth rate of the population, strong rural exodus, rapid urbanization and
5 The increasing divergence between agricultural production and consumption systems.

Indeed agriculture did not respond positively to the new economic environment created by macroeconomic policies and sectional policies reforms initiated by Senegal. The recovery conditions of agricultural production do not seem to be satisfied. Credit access, water management, input supply and product marketing are current difficulties hindering the improvement of the domestic production. These constraints are increased by the deteriorating terms of agricultural product trading as well as the reduced profitability and competitiveness of agricultural products.

2.3.1 Biophysical factors

Senegal's agriculture sector is facing a number of environmental constraints. Depending on regions, these constraints include:

1 Low and irregular rainfall,
2 Salinity, acidification, toxicity, and wind erosion of soil,
3 Reduction of grazing areas and overgrazing,
4 Reduction in area of forest formations with the vegetation destruction,
5 Advance of sand dunes and remobilization of ancient dunes,
6 Filling and sanding of shallow lands,
7 Risk of rupture balance between fresh water and salt water in the underground and 8 The threat of seawater intrusion.

2.3.2 Socio-economic factors

The main socio-economic factors causing Senegal's domestic production shortage are (WAAPP, 2009):

1 Constraints of increasing harvested area
2 Constraints in production increase
3 New technology use constraints
4 Certified seed use constraints
5 Institutional factors

2.4 Reflections on the adaptive research to improve Senegal's agricultural production

The yield gap between the potential yield and farmers' average yield is still substantially high in rice and maize production in Senegal. However, if for the maize the main efforts of governments on yield improvement are still vainly achieved, for rice, these two last years were very constructive in this gap narrowing. This positive result is due to the big expert of Senegal River Valley farmers who produce 70% of the domestic production in two seasons; the rain fed and irrigated seasons. Its gap in maize production is also small. SRV performance in rice and maize farming shows and confirms the huge potential of this area in the improvement of cereals production as well as in the achievement of self-security.

In order to sustain agricultural production and productivity, combined manageable constraints which caused the yield gap should be properly adjusted along rice and maize sectors to enhance their production. For that there must be a wide collaboration between actors: scientists, monitors, farmers as well as private and public institutes (mainly financial institutes). This cooperation is imperative in yield gap narrowing. Indeed the yield gap narrowing will not lead only to the improvement of yield and the domestic production it will also improve the efficiency of land and labor use and decrease exploitation costs while increasing its profit sustainability. For that, policymakers who are fully aware of the advantage of yield gap narrowing were and are still working on the key factors of yield improvement.

These key factors are:

1 Government policy support,
2 Promotion of integrated crop management in maize and rice farming,
3 New proven technologies deployment,
4 Identification of spatial strategy according to each locality's comparative advantages and 5 Participative management strategies.

3. Yield gap narrowing

Increasing rice and maize output are the primary goals of GOANA program launched in 2008. The program aimed to reduce imports and achieve national self-sufficiency in food by 2015. As yield gap remains higher than expected and given the availability of all technology packages, priorities should be focused also on the divulgation of agricultural practices as well as their adoption by farmers (Krupnik et.al, 2012 and IPTRID/SENEGAL 2004).

The concept of yield gap narrowing is not just static but dynamic. And according to the population and urbanization growth rate of Senegal which is respectively 2.56% and 46.8% (ANSD, 2011), like anywhere in the world, priorities should be focused on intensive and efficient agricultural production rather than on traditional practices. In the country (Senegal River Valley) the yield gap in rice and maize are respectively 49.75% and 79.75% (37.9% and 58.75%) in 2011. These percentages show big challenges that are facing policymakers. For that "efforts should be made to update farmers' knowledge on the causes of yield gaps in crop and measures to narrow the gaps through training, demonstrations, field visits and monitoring by extension agencies to achieve high yield" (Mondal, 2011). In addition, the improvement of crop yield and the achievement of food security rely on good agricultural practices (Lobell, Kenneth, Cassman and Field, 2009) as well as R&D on cultivars and fertilizers improvement (Seck et.al, 2010; Saito, Futakuchi, 2009 and Africa rice, 2008).

Indeed for many years' governments held vainly many strategies to boost cereal production, mainly rice one; in order to make them available at affordable prices to consumers for economic growth, social security and political stability (Singh et.al, 2011) of the nation. And as draught, lack of infrastructures and production skills, water scarcity (groundwater pollution and reload matter of groundwater, superficial water chemical pollution which implied the creation of many projects and programs for water management) are some of the main barriers to Senegal's agriculture sustainability and according to the context socio-economic of producers, efficient agricultural production, as well as sustainable management of natural resources, is imperative. For that in order to secure the current and future generation needs, priorities should rely on sustainable and efficient production through more efficient land preparation (tillage conservation) and water use (De Datta; Cannell and Hawes, 1993 and Elwell, 1993) as well as integrated pest and nutriment management (Seck et.al, 2010; World Bank, 1993 and Africa Rice, 2011).

Indeed, good agricultural practices follow up combined with a good weather (efficient quantity while better spatial repartition of the rain) increased the rice productivity by 18% in 2008 compared to 2007. Furthermore, grain quality does not depend only on the crop production environmental but also on harvesting, processing, and milling or shelling systems.

Thus, post-harvest activities amelioration may decrease de variation of losses while conserving the quality and tastes of grains (Dr Manful, IRRI and FAO, 2008). The key factors to narrow considerably rice and maize yield gap while improving their quality are:

1 Agricultural practices steps follow up in order to ease:
   - Weed control
   - Fertilizers incorporation ease,
   - Porosity and aeration increase and
   - Fine tilth of soil to increase the adsorption of nutrients (De Datta, 1981).
2 Land leveling and grading
3 Water management for efficient agricultural production
4 Fertilizers and pesticide management for healthy crops
5 Best management of harvest and post-harvest activities to increase productivity and maintain the quality of grains.
6 Adequate equipment in agricultural products processing.

4. Conclusion

The improvement of farmers' average yield is the main concern of policymakers. To this score, many strategies were and are taken to enforce their capacities. Thus, numerous R&D on fertilizers, pesticides, and insecticides in order to improve them as well as appropriate agricultural practices and equipment (in the entire sector) were made to boost the domestic agricultural production.

Nonetheless, there is still a huge gap to fill mainly in rain-fed agriculture. In the irrigated sector, for the rice and maize, non-negligible results have been realized, mainly in SRV where the current yield gap are respectively 37.9% and 58.75% of the potential yield. These results are correlated to the perfection of agricultural production factors and innovation in agricultural practices. However, some constraints are still persisted due to the less mechanization factor in this century of the technology boom.

The main principal handicap in crop production is the respect of conventional land preparation which includes land tillage, leveling, first fertilizers amendments and others due to its huge cost which is almost beyond farmers' financial capacity. And the minimum or zero tillage is not going to settle this matter for many reasons like:

1 Unavailability of crop residues as all residues are used to feed cattle,
2 Shortage of labor to deal with initial high weed infestation,
3 Unavailability of appropriate and necessary agricultural materials to realize some agricultural operations such as planting and weeding,
4 Leveling conservation, etc.

Furthermore, these constraints are increased by harvest and post-harvest activities issues. Indeed if harvest and postharvest activities are not well done, grain quality will be affected physically (color, weight, broken...) and nutritionally (taste, nutrient composition). In SRV the main postharvest concern in rice production relies on the processing system. Most of the machines in use are not appropriate to local rice varieties and cause heterogeneous milling rice in absence of grading machine. Due to that, population preferred and prefers the imported rice for it already to cook characteristic.

In order to boost sustainable cereals production, governments, NGO, farmers, communities and other organisms of development should focus efficiently in the improvement of post-harvest technologies. The packaging must also be revised considerably even though some improvements are done in the SRV by using new bags instead of already used of imported cereals like rice or other plastic boxes.

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ACRONYMS AND ABBREVIATIONS

ANCAR: National Agency of rural executive Managers (Agence National des Cadres Ruraux)

ANSD: National Agency of Statistics and Demography (Agence Nationale de la Statistique et de la Demographie)
CNCR: National Framework for Dialogue and Rural Cooperation (Conseil National de Concertation des Cadres ruraux)
CNRA: National Council of audiovisual regulation (Agence Nationale de Regulation de l'Audiovisuel)
CPAR: Country Program Assessment Review
DRDR: Regional Office (Direction) of Rural Development (Direction Regionale du Developpement Rurale)
FAO: food and agriculture organization
GOANA: Great Agricultural Offensive for Food and Abundance (Grande Offensive Agricole pour la Nourriture et l'Abondance)
IPTRID: International Program for Technology Research in Irrigation and Drainage
IRRI: International Rice Research Institute
ISRA: Senegalese agricultural research institute (Institut Senegalais de Recherches Agricoles)
MEF: Ministry of Economy and Finance
NERICA: New Rice for Africa
NGO: Organization Non Governmental
OFS: Office of Food Security
PADERBA: Anambé Basin Rural Development Support Project (Le Projet d'Appui pour le Developpement Rural du Bassin de l'Anambé)
PROMER: Promotion of Small Rural Entreprises (Promotion des Micro-Entreprises Rurales)

REVA : Retour vers l'Agriculture (Reversion to Agricultural)
SAED: Senegal River Valley National Development Agency
SODEFITEX: Textile Fiber Development Company
SRV: Senegal River Valley
WAAPP: West Africa Agricultural Productivity Program
WARDA: West Africa Rice Development Association