Optimization of rice production in the Nanan rice perimeter (Yamoussoukro-Côte d'Ivoire)

Project Coordinator:

Dr KONAN-WAIDHET Arthur Brice,

Maître de Conférences, Télédétection, SIG et Environnement

Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire

konanwab@yahoo.fr / arthurwaidhet@gmail.com

Project Beneficiary Partner:

COopérative des **PRO**ducteurs de **RIZ** (**COPRORIZ**)

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CONTENTS

1- EXECUTIVE SUMMARY

Irrigated rice cultivation, the leitmotif of the policy of food self-sufficiency in Côte d'Ivoire, is failing. Although worrying, the increase in the demand and consumption of rice may constitute an opportunity to consolidate rice self-sufficiency, increase farmers' sources of income and fight poverty. However, the development of this sector requires institutional, technical and financial support to enable producers to increase their production and improve their standard of living.

2- INTRODUCTION

Rice is one of the strategic food commodities in Africa. In order to avoid any risk of food insecurity in Côte d'Ivoire and reduce its dependence on the outside world, the State has therefore set up hydro-agricultural facilities throughout the country. However, these schemes, such as the one from Nanan to Yamoussoukro, have not been satisfactory in terms of yield per hectare. However, in the irrigated rice system, it is possible to carry out two (2) or even three (3) cropping cycles per year. Moreover, the constant low yield leads to a drop in the economic income of the producers and is one of the main causes of the progressive abandonment of rice cultivation by some farmers in favour of other speculations.

This research addresses the problem of low yields per hectare in irrigated rice cultivation throughout the country. Can we not speak of failure when we imagine the large sums of money disbursed by the government for the creation of these rice-growing perimeters? How did this decline come about?

Faced with this sad reality, we undertook this study with the aim of improving rice yields on this perimeter in order to enable farmers to receive significant enough income to meet their needs. In order to achieve this objective, we decided to : : (i) determine the performance indicators of the perimeter, namely efficiency and productivity and identify drainage problems; (ii) monitor the management of fertilizers and the agricultural calendar; (iii) carry out an analysis of the governance of the perimeter by COPRORIZ; (iv) strengthen the technical and organisational capacities of COPRORIZ through the rehabilitation and maintenance of irrigation and drainage networks; (v) set up a monitoring-evaluation system using decision support tools.

Thus, this study not only made it possible to identify the problems that hamper the expected productivity in irrigated rice cultivation, but also to set up decision-support tools for sustainable management of the perimeter. It proposes solutions to remedy the poor performance observed. It is testing technologies for rice cultivation and strategies for developing an integrated crop year calendar.

3- METHODOLOGICAL APPROACHES AND RESULTS

To achieve our objectives, we undertook several activities, namely: holding a scoping meeting, determining performance indicators, monitoring fertilizer management and the agricultural calendar, analyzing the governance of the rice perimeter and, finally, strengthening the technical and organizational capacities of COPRORIZ, and using decision-support tools to envisage monitoring-evaluation.

3-1 <u>Orientation meeting</u>

This meeting was held in Yamoussoukro on 01 June 2019 in the premises of COPRORIZ (Figure 1). It served as a framework for presenting the project and its objectives, explaining its different stages, clarifying the roles and responsibilities of stakeholders and providing support to the project team. It was also used to obtain the support of all the rice producers in the area.

Figure 1: Orientation meeting

3-2 <u>Determination of perimeter performance indicators</u>

The performance indicators of irrigation efficiency and water productivity have been calculated from certain land parameters through mathematical formulas. These indicators make it possible to judge the efficiency of irrigation on the Nanan perimeter and consequently the contribution of water input on rice yield. In addition, drainage problems have been noted

- Overall irrigation efficiency (EI) is defined at the perimeter as the product of water transport (ET) and plot application (EA) efficiencies..

The concept of transport efficiency expresses the ability of the transport system to deliver and distribute water without losses. On a given section, transport efficiency is determined by the ratio between the outflow and inflow of that section on which there is no water supply.

The application efficiency at the plot scale therefore expresses the degree of water losses that may occur in the irrigation system installed at the plot as well as in the application of water to the crop.
The method used to determine application efficiency is to measure the amount of water "actually applied" to the plot and the amount of water "actually used" by the crops on that plot, i.e. the amount of water actually consumed by the crops. Generally, the water used is assimilated to the crop's evapotranspiration (ETM) accumulated during its development cycle), i.e. to the rice's water requirements.

The EA plot application efficiency (%) is determined by the quotient of the amount of water consumed by the rice (EC in mm) and the amount of water applied to the plot (EP in mm).

In the research on perimeter performance, three plots were selected along the primary perimeter channel : (upstream, central and downstream). The choice of plots was made with a view to covering the whole of the currently irrigated perimeter, describing the behaviour of the stakeholders, and explaining water management on the perimeter, at plot level.

The results of the hydraulic measurements reveal that the overall irrigation efficiency of the perimeter is low and is in the order of 35%.
The water transport efficiency on the Nanan perimeter, after deduction, is 81.5% with water losses of 18.5%. Moreover, we could observe at the end of the network, that there are neither rice plots under development, nor plots in preparation and yet a flow of 6.45 l/s continues to flow in the form of waste in nature. The transport efficiency of 81.5% hides important weaknesses, mainly the lack of maintenance of the main canal.

As for the efficiency of application of the perimeter deduced from plot level efficiencies, it is 39.1% for losses of 60.9%, which is mainly due to the low level of training of the rice farmer in irrigation techniques and poor irrigation planning on the site. What about water productivity?

- Water productivity measures the increase in output per unit of water used.

It is also the ratio between the yield (grains, total biomass) and the amount of water consumed by the crop or the amount of water brought to the crop to achieve this production. This amount of water supplied to the crop includes the raw irrigation water, i.e. the water delivered to the plot (EL) and the effective rainfall (Pe) during the production cycle. It was determined on one of the two test plots.

The results give a water productivity of around 0.42 kg/m3 , below the recommended values (0.6 kg/m3) and which is essentially due to inappropriate irrigation management on the perimeter. The hydraulic system that drains water from the reservoir to the plots is in an advanced state of degradation.

Water productivity gives meaning to irrigation efficiency. It assesses plot and irrigation efficiency. Water productivity can be converted into monetary gains in the market. Overall, the results obtained thus reveal a low performance of the hydraulic network in the Nanan irrigated rice perimeter. A soil analysis would certainly be useful to assess its impact on irrigation efficiency.

- Study of the physical characteristics of the soil and its impacts on the irrigated perimeter.

Soil samples were taken and analyzed at the Pedology Laboratory of the Institut National Polytechnique Félix Houphouët-Boigny (INP-HB), located in Yamoussoukro. The analyses made it possible to characterize the texture of the soils of the perimeter as well as the infiltration of water on the site.
Soil texture was obtained from the granulometric analysis of twenty-one (21) samples taken on the site. These twenty-one (21) samples were taken and used to establish a soil classification. For this purpose, from the granulometric analysis the proportions of the different grain sizes were determined.
It emerges from this analysis that, relative to the surface area of the perimeter, four (4) types of soil were recorded, of which silty soils occupy 38.09%, silty-sandy soils 42.85%, silty-clay-sandy soils 9.52% and sandy-silty soils 9.52%. Permeability measurements using the double ring method were carried out in-situ.
The results obtained show differences in permeability according to soil texture (the infiltration rate (k) varies from 0.33mm/h to 1.23mm/h) The relationship between permeability and efficiency is shown in Figure 2.

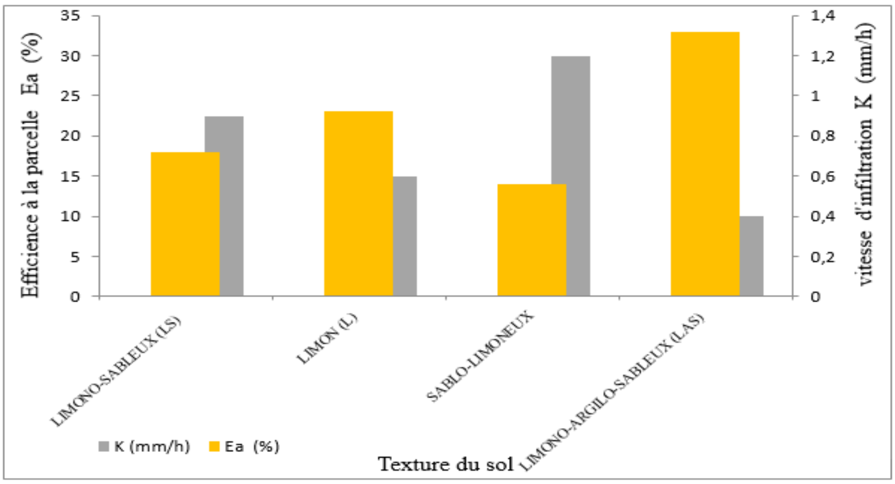

Figure 2: Average plot permeability and efficiency on the Nanan irrigated rice perimeter

t emerges from this graph that the soils with the highest application efficiency are silty-clay-sandy (32.95%), but is still far from the normal rate of 65%.
Silt soils come in second place with an efficiency of 22.74%, followed by silty-sandy (17.17%) and sandy-silt soils (13.92%).
However, silty-sandy or sandy loam soils, which are of low irrigation efficiency, are the most widespread on the site.

The study shows that the notable absence of clay in the soil composition is a handicap to tend towards optimal irrigation efficiency, synonymous with water saving.
Rice cultivation is a water-consuming crop. Indeed, according to the study, if infiltration losses were considerably reduced, at least two cycles of rice production would take place each year, and three in years with excess rainfall. But the impact, if not the pressure of infiltration on efficiency, and therefore on rice productivity, is too strong and negative enough to be ignored.

Additional research focusing on cropping techniques should be undertaken with a view to possibly mitigating this negative influence of soils on irrigation efficiency.

What analyses can we make of fertilizers and the cropping calendar?

3-3 <u>Monitor fertilizer management and crop scheduling</u>

The question of fertilizers and the crop calendar is based on the findings of the field visits.
First of all, the condition of the soil in the rice field must be taken into account, with the help of half-yearly or annual analyses, before applying any fertilization method. No two soils are the same, and we do not want to rush into proposing other methods of fertilization without taking into account the data from the chemical analysis of the soil, which we have not yet carried out due to lack of resources. However, in the majority of cases, farmers use NPK, according to their means, which are not always

With regard to the cropping calendar, the diagnosis shows that not all rice farmers in Nanan use improved seeds. Those who do not use improved seed, are re-growing some of the paddy taken from their own production.
These seeds are then not pure and therefore compromise productivity, as the presence of diseased or non-performing grains leads to a low germination rate. In addition, farmers do not all start the growing season at the same time.

However, a review of the crop organization on the perimeter indicates that it is possible to do two cropping cycles of an average of 120 days. The first cycle starts in January and ends in mid-June. The second cycle runs from July to December. This standard calendar was developed based on the constraints identified by the rice farmers. Thus, during the period of :
- heavy rains, avoid harvesting (June - September)
- harmattan (dry wind) avoid heading (December-February)
- falling prices, avoid marketing.

3-4 <u>Analysis of the governance of the perimeter by COPRORIZ</u>

The general governance of the perimeter is generally the responsibility of COPRORIZ. The series of interviews with the various stakeholders and during the visits to the perimeter have enabled an overview of the level of management of the site, irrigation and the state of the irrigation infrastructures of the perimeter.
Throughout the perimeter, the Development Management Committee (CGA), in charge of water management, is confronted with a lack of compliance with the decisions taken during the meetings. As not all the farmers start the cropping campaigns together, the remark made is that it is difficult to rigorously respect the method of water distribution per water tower and the irrigation calendar throughout the perimeter. Indeed, the irrigation units that should be supplied by rotation on irrigation

days are no longer being supplied. Water is distributed to the plots on a continuous basis, whether or not a rice farmer uses it. The opening times of the dam are also affected by this state of affairs.

With regard to hydraulic works, the fact is that the hydraulic infrastructures of the Nanan rice scheme are in poor condition for the most part. At the start of the project, the primary canal was suffering from a serious problem of silting and grassing along its entire length and in its surroundings (Figure 3).

Figure 3: Photographs illustrating silted and grassed canals

Secondary drains are virtually non-existent along the entire perimeter. Each farmer has to take care of the maintenance of the section of the primary canal that serves his plot himself. However, this is not done on the entire perimeter. Furthermore, it can be seen that the main canal is cracked and destroyed in some places along its length (Figure 4), especially at the joints.

Figure 4 : Photographs illustrating the degraded main channel (breaks and cracks)

These breaches allow a considerable amount of water to leak out. In addition, almost all the mobile valves of the irrigation intakes serving the plots are no longer properly functional.

As far as maintenance is concerned, COPRORIZ will have to reinforce the authority of the Management Committee of the developments in charge of the hydraulic network in order to avoid all kinds of drifts. The responsibility for the maintenance of the hydraulic network must be perfectly defined. It therefore appears, in view of these observations, that the main factors acting on irrigation efficiency and water productivity in the Nanan irrigated rice perimeter are of an organisational and technical nature.
COPRORIZ will have to make available to the head of the Development Management Committee the necessary human, financial and material resources to enable him to deal with any kind of network dysfunction.

3-5 **Strengthen the technical and organisational capacities of COPRORIZ**

Le renforcement des capacités permettra la réhabilitation des canaux d'irrigation et un meilleur suivi-évaluation à travers l'usage d'outils d'aide à la décision.

- Trainings

Training on governance (organisation and operation of COPRORIZ), as well as on water management (irrigation efficiency and water losses, network maintenance, irrigation calendar, dose, frequency, periodicity, module, irrigation duration, identification of irrigation and drainage networks, cycle timing, water productivity) were provided to the stakeholders (Figure 5). Information was also provided to them on the Soil Texture which induces a significant stabilized permeability negatively impacting the availability of the water resource stored in the hill reservoir.

Figure 5 : Training carried out on the perimeter with the farmers

In addition, farmers were encouraged to follow and respect the watering schedule.
The perimeter was divided into two (2) irrigation blocks called daily irrigation units (U1 and U2).

In order to have a good production, the units must be served according to an irrigation calendar and dam opening times. This necessarily involves respecting the watering time.
In order to achieve good monitoring, farmers should sow the seedlings at the same time. On the perimeter, we found that there is no discipline; each one has his own sowing and ploughing schedule independently of the others, so they can have water permanently on the perimeter.

- Rehabilitation of the hydraulic network

In order to improve irrigation efficiency, we have rehabilitated some structures and dredged the main canal (Figure 6).
In fact, after a diagnostic study of the irrigation network of the Nanan perimeter, manpower was deployed for the cleaning and dredging of the primary canal. In addition, some stop valves were repaired and rehabilitation of some, but not all, sections of the main canal was undertaken.

Figure 6 : Mobile gate repaired and main channel cleaned and rehabilitated

- Labour

Always with the aim of helping rice farmers to improve production, because it has to be said that there is a lack of motorized equipment for ploughing, we have therefore rented a motorized cultivator to help them. Thus, two (2) experimental plots were chosen. For this purpose, ploughing and soil preparation were carried out with a tiller and a tractor (Figure 7).

Figure 7: Ploughing work with a tiller

On an experimental basis, fertilizer and seeds were provided on these experimental plots to show them by example how to follow the technical itinerary. This is the chronological succession of operations starting from the semi of a crop to its harvest on a given plot. It particularly influences the success of speculation on a farm The respect of the technical itinerary is a very important factor in the production of irrigated rice. Poor execution of operations negatively affects yield.
The average yield on the experimental perimeter was 4.5 tons/hectare before the works. Accompaniment on these plots respecting all the conditions of the cultivation techniques with the support of the UAV was able to give a yield close to 7.3 tons/hectare (Figure 8).

Figure 8: Experimental plots at maturity

3-6 <u>Implementation of a monitoring-evaluation system through the use of decision-support tools.</u>

How can we ensure that the knowledge gained from this study is retained? Certainly by accompanying producers through decision-making tools. In terms of these tools, we have considered two approaches:

The first approach concerns the use of a UAV. Indeed, it is an innovative device that optimizes the yield of agricultural land thanks to its multiple functionalities. The images taken by the georeferenced sensors give precise indicators that will be used to improve productivity. Thus, thanks to its multi-spectral sensors, the UAV makes it possible to: carry out management plans; diagnose areas of disease, the least fertile or least hydrated areas and provide appropriate treatments; manage water resources and save inputs. We have therefore acquired a drone (Figure 9) that has been tested on a single cropping cycle with satisfactory results, but which will be deployed over the entire rice perimeter in the next cropping cycles by starting ploughing and sowing at the same time.

Figure 9 : Drone for crop monitoring

The second approach is the development of a database and platform. Based on the results obtained, we began by developing a database to capitalize all the data collected on the perimeter in order to facilitate future actions to be carried out on the perimeter (Figure 10). This information system should eventually lead to a platform where producers will have access to updated information on their plots, photos, videos, reports and figures on their farms. It will also be an opportunity to have access to the external market for added value of their activities.

Figure 10 : Rice perimeter information system

4- IMPLICATIONS AND RECOMMENDATIONS

With low overall irrigation efficiency, water losses on the irrigated perimeter between the collinear dam and the included rice basins are very high. Thus, the study shows that it is essential to determine the deep percolation in the field to achieve a better appreciation of the irrigation efficiency. This would allow a better appreciation of hydraulic and agricultural productivity. The habit of using for the calculation of irrigation efficiency the usual values of infiltration indicated in the general literature according to soil texture should henceforth give way to the collection of real data in the field by in-situ measurements, otherwise irrigation efficiency, which is a reference indicator, will always be seriously biased, and with it, the hydraulic or rice productivity that we want to correct and improve.

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The practice of irrigated rice cultivation contributes to a healthy conservation of the environment and protection of the forest. It is different from shifting cultivation, which promotes climate change.

Thus, at the same time as the technical difficulties are addressed to absorb water losses in the soil, emphasis must be placed on training rice farmers in irrigation and water management, cultivation practices, and the influence of climate on the resource. Good water management contributes to yield improvement, so any opening of the sluice gates at the head of the perimeter should correspond to a real need of the perimeter. For this reason, the presence of a person in charge of the gates is recommended within the Management Committee.

In view of the lack of discipline in the irrigated perimeter, it is advisable to set up a participative governance tool or a consultation platform. This would encourage permanent consultation of the various stakeholders working on the perimeter and promote the circulation of information on the sustainable development issue. This platform will be both deliberative and consultative and will serve as an interface between the public sector, the private sector and donor partners. It is therefore necessary to inculcate in producers a paradigm shift for better management of the perimeter's resources, which will guarantee better production.

Furthermore, research must continue to confirm the good trend of the first results obtained, such as yield per hectare.

CONCLUSION

With a low irrigation efficiency, water losses on the irrigated perimeter between the collinear dam and the included rice basins are very high. There is also low water productivity on the perimeter. At the level of soil texture, the absence of clay considerably reduces the irrigation efficiency of the rice basins.

Moreover, the study shows that it is absolutely necessary to determine the deep percolation in the field to obtain a better irrigation efficiency. This would allow a better appreciation of hydraulic and agricultural productivity. The habit of using for the calculation of irrigation efficiency the usual values of infiltration indicated in the general literature according to soil texture should henceforth give way to the collection of real data in the field by in-situ measurements, otherwise irrigation efficiency, which is a reference indicator, will always be seriously biased, and with it, the hydraulic or rice productivity we want will be worth correcting and improving agricultural yield.

Rice growers must review the methods of cultivation practices. Irrigated rice cultivation can allow the farmer to live decently if he succeeds in "taming" infiltration and drastically reducing water losses on the Nanan plots, which make up nearly 80% of the water flowing through the dam. Reducing these losses requires a study on cultivation methods.

Furthermore, it is essential that rice farmers take care of the irrigation network and organize themselves for its maintenance and in case of failure. They must ensure preventive maintenance (cleaning, plugging breaches) and periodic maintenance (cleaning canals and drains, repairing embankments) of the perimeter.

Emphasis should be placed on training rice growers in irrigation and water management and cultivation practices. Any opening of the gate at the head of the perimeter should correspond to a real need of the perimeter. In this sense, the presence of a person in charge of the gates is recommended.

In view of the lack of discipline on the irrigated perimeter, it is advisable to set up a participative governance tool or a permanent consultation platform for the various stakeholders working on the perimeter, as well as the circulation of information on the sustainable development issue.

Studies have also shown that it is possible to improve yields per hectare with the help of UAVs and the respect of cultivation instructions. However, monitoring could only be carried out during a single cropping cycle. It would be desirable to confirm this technology through other cropping cycles. The importance of this technology deserves that this study be continued for the well-being of rice farmers. However, the UAV's capabilities will only be effective if farmers are able to start the agricultural seasons at the same time. It is an innovative tool that will make it possible to considerably increase yields.

As a constraint, the irrigated rice perimeter of Nanan, despite the presence of a hydro-agricultural dam, is facing a water shortage, accentuated by significant infiltration losses that will have to be truly rectified through studies to be conducted on cultivation methods and by respecting irrigation parameters (flow rate, dose, irrigation duration, frequency, monitoring of the agricultural and irrigation calendar). The work carried out is first experimented on two(2) control plots. It is now planned to extend the study to the entire perimeter.

In view of the organizational difficulties, CORPRORIZ is invited to review its management method, which must be more participative and anticipative and must be set up in a legal operating framework with a legal status and regulatory texts.

The practice of irrigated rice cultivation contributes to a healthy conservation of the environment and to the protection of the forest. It is quite the opposite of shifting agriculture, which favours climate change.