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Abstract:

Small irrigation schemes have become very popular in many African countries as a policy measure to boost agriculture and farm income given their relatively low capital investment compared with to large irrigation infrastructures and the shorter time required for the project design and implementation. This paper attempts to explore the likely impacts of a program of small irrigation development in Niger on land allocation, agricultural production, food security and poverty reduction on a nationally representative sample of farm households. A farm-household model, named FSSIM-Dev (Farm System Simulator for Developing Countries), is used to achieve this objective. This static positive programming model was applied to every individual farm household included in the 2011-2012 LSMS-ISA survey sample – around 2300 farm households – in order to guarantee the highest representativeness of the farming systems and to capture the full heterogeneity across farm households. Results show that irrigation has a large impact on agriculture production and income of smallholder farmers, mainly during the dry season and in the regions with high potential irrigable land. Farm income would increase by around 7 % at country level if small irrigation was made available to all farmers. At the regional and individual farm levels the impact is more pronounced (reaching more than 80 % in one region). Additionally, the income impacts are larger for those households with the lowest agricultural income in the baseline, showing the large potential impacts of small irrigation in terms of poverty and inequality reduction.

1. Introduction

Niger is a landlocked country of Sub-Saharan Africa that belongs to the Least Developed Countries according to the classification of the UNDP. It is chronically in a situation of food-deficit. According to the last population census (INS, 2012), it has a population of approximately 17.1 million people, of which about 80% live in rural areas. The 2013 Human Development Report of 2013 (UNDP, 2013) ranked Niger last country in the world (186th) in terms of Human Development Index, and more than 75% of its population live with less than 2 USD per day. However, the extreme poverty rate has decrease in the last decades, from 63% in 1990 to 48% in 2011. The GDP per capita has also increased by almost 70% between 2000 and 2012, to reach approx. 320 EUR per capita.

Another important aspect related to Niger is its current population boom. According to World Bank figures, the annual growth rate of the population averaged 4% over the 2011-2015 period, which makes the country to rank third in the world for population growth (World Bank, 2016). This impressive population growth has important consequences in rural areas, and results in an increased pressure on land. Between 1980 and 2005, there was a drastic reduction of the ratio of arable land to agricultural worker, from 11.8 to 5.1 hectares per worker. According to the last census, this reduction continued to 2012 with an estimated ratio of 1.1 hectares (INS, 2012).

The development of the agricultural sector in Niger is critical to achieve overall growth in the country and food security of poor households. In fact, there have been lots of efforts focusing on the development of the national agricultural production in order to meet the growing demand of the rural and urban population. Water being a limiting factor for agricultural production in most of the country, the development of irrigation has always been regarded as a key aspect of this development of the sector. In the last decade, the focus has been placed to the development of small irrigation perimeters, whose implementation is less consuming in terms of capital and time than large infrastructures. The objective of this paper is to assess the potential impacts of a small irrigation program currently under development in Niger, on irrigated land allocation, agricultural production and agricultural income, using a representative sample of 2,300 farm households drawn from a comprehensive survey conducted in 2011.

2. Situation of Agriculture and Rural Development in Niger

The agricultural production in Niger faces very hostile conditions, due to the arid climate regime of the country characterized by low rainfalls, a short rainy season and high temperatures. Despite of these adverse constraints, agriculture is the most important sector of the economy in Niger, from both a social and economic point of view. More than three-quarter of the population is active in agriculture (INS, 2012), while the sector contributed to about 45% of the GDP in 2010. The agricultural sector has actually grown faster than the other sectors of the economy over the last ten years. It is also the second sector contributing to export revenues after mining, primarily through the export of living animals and agricultural products such as onions or sesame to its neighbouring countries (Ministère de l'Agriculture, 2014).

Most of the agricultural production relies on small family farms, generally less than 2 hectares. The typical rain-fed agricultural systems are based on staple crops such as millet and sorgho, most of the time in mixed cropping systems with legume crops such as peanuts or *niebe* (black-eyed pea i.e. *Vigna unguiculata)*. When they have access to irrigated land, farmers generally add to the previous crops some vegetable products, such as onions or sweet pepper. Overall, irrigated crops contribute to 30% of the value added of the agricultural production and up to 90% of the exports. This vegetable production represents the only source of cash for many agricultural households, in the absence of other alternatives.

Besides the obvious agro-climatic constraints that the agriculture production in Niger is facing, there are other barriers that could be more easily lifted. Access to most of production factors (agricultural inputs and equipment) or to extension services is still limited for most farmers. Market access is also hindered by an underdeveloped road network and poor market facilities. Access to credit is virtually inexistent for farmers. In addition, the country is also on the front line for the negative impacts of climate change. It could suffer significant drops in cereal yields if it fails to adapt the agricultural systems to the changing climatic conditions. Due to the high importance of cereals in the diet of most agriculture households, the consequences for the food security and the nutrition of the population could be dramatic.

Therefore, the challenge for Niger Agriculture will be to better manage the water supply and the soil fertility. The yields of cereal and vegetable products could be increased and their variability reduced thanks to the use of improved variety, the adoption of anti-erosion techniques, the increased use of animal traction for farming operations, or the introduction of agro-ecological innovations. A better exploitation of the water from rainfalls, together with a better management of irrigation systems to improve water efficiency also represent an important development lever for the agriculture production in Niger. The improvement and stabilization of agricultural yields would allow agriculture household to meet their subsistence needs and to generate some surpluses for sale. This would in turn strengthen their resilience to climatic change.

To support the development of its agriculture sector, Niger has adopted in 2012 a common framework for all rural and agriculture policies, called the “Initiative 3N”, that stands for “*Les Nigériens Nourrissent les Nigériens”* i.e. Nigeriens feed Nigeriens. The main goal of this initiative, and of its further *plan d’accélération* adopted in 2014, is to foster the domestic production of food products, in order to build up the supply side and the resilience of the country to food crises and natural disasters (HCi3N, 2012). This development of agriculture is also supposed to be in line with the principles of sustainable development.

Within the Initiative 3N, a strong emphasis has been placed on the development of the Small Irrigation. This is the result of different findings. First of all, the cereal yields in Niger have been decreasing over the last decades, as a result of different factors such as soil degradation, shortening or disappearance of fallow periods between cropping periods and increased pest pressure. Irrigated crops such as vegetable production are therefore regarded as an alternative to cereals. Second, irrigation allow to stabilize yield faced to erratic rainfalls and to expand virtually the cropped area by using the land during both the dry and the rainy seasons or by cultivating land that cannot be used during the dry season (for instance in the riverbed of temporary watercourses, where humidity remains at low depth during the dry season). Finally, small irrigation is also regarded as a viable alternative to the large hydraulic installations that have been the priority until the end 1990s, and whose profitability and management turned out to be complex (Ministère de l'Agriculture, 2015).

The previous elements have contributed to a change in the rural development strategy of Niger. It now focuses on the development of small irrigated perimeters, at village scale, and managed locally. This new priority has led the Ministry of Agriculture to elaborate a specific strategy for the development of small irrigation, in the framework of the *Initiative 3N*, namely the *Stratégie de la Petite Irrigation au Niger* (SPIN) (Ministère de l'Agriculture, 2015). The objective of the SPIN is to increase the participation of irrigated land to the achievement of food and nutrition security in Niger, to boost agricultural productivity and to increase the resilience of rural households faced with climatic hazards. In concrete terms, the government will support small irrigation projects proposed by local authorities, villages or groups of farmers, in exchange of a financial or physical (work) participation from the beneficiaries. Small irrigation infrastructures have the benefit to be flexible and to be easily adapted to many different local situation and source of water (surface water, groundwater, rainfalls). The most common forms of small irrigation infrastructure that the SPIN intends to developed are: wells and shallow forage (less than 15m deep) with pumps, creation of agricultural ponds, small hillside catchment reservoirs, river weirs, small pumping stations for permanent watercourses, etc.

The SPIN is supposed to start operating and to grant its first funding for small irrigation projects in 2016. This strategy is intended to last for the next ten years.

3. Materials and Methods

3.1. Farm household models: overview and illustration with FSSIM-Dev

How to measure food security has been a point of debate in recent years due the multidimensionality of food security (food availability, food access, utilisation and stability) and the time span to be considered. Different approaches, either qualitative or quantitative, have been developed to assess and/or proxy the impact of policy and technology on food security at micro and macro levels. For instance, food availability has been estimated through econometric techniques (Oluyole et al., 2009, Feleke et al., 2005, Larochelle and Alwang, 2014) or measures through specific surveys based on indicators such as dietary energy supply per capita or household expenditure.

Farm and farm household models have also been used for the assessment of policy and market impacts on food security and poverty alleviation, especially in developing economies. Farm household models are well suited for taking into account the peculiarities of rural economies in low income countries where production, consumption and labour allocation decisions are non-separable due to market imperfections (Singh et al., 1986, De Janvry et al., 1991). Such models are able to take into account the effects of transaction costs on market participation decisions. In sum, farm household models represent a useful tool to capture key feature of the agricultural sector in developing countries and to assess the systemic effects of policies on farming systems. They can provide information on resource uses, agricultural production, changes in crop rotation, food consumption, participation to input and factor markets, agriculture and household income, poverty level, etc. All data can be generated at household and aggregated level, which can also give the distribution of any impact across all farms, and not only average effects. Louhichi et Gomez-y-Paloma (2014) have recently reviewed the studies based on farm household model in developing countries, stressing the advantages and drawbacks offered by the different methodology, geographical coverage and behavioural hypothesis used.

In this study, we use a farm household model called FSSIM-Dev (Louhichi and Gomez y Paloma, 2014) to *ex-ante* assess the impacts on smallholder farmer livelihood and on food security of the deployment of a small irrigation scheme in Niger. FSSIM-Dev is a micro-simulation tool that is well adapted to assess the policy impacts on food security and rural poverty alleviation in the specific context of low-income developing countries. As every farm household models, it solves simultaneously the household's production and consumption decisions. However, contrary to most other household models, FSSIM-Dev is a positive programming model and this makes it able to properly reproduce the observed situation taking into account the existence of implicit costs not always captured in the dataset used to calibrate the model.

FSSIM-Dev model reproduces the dual character of farm households in developing countries. In particular, food surplus/deficit is created as a difference between food and cash crop production and household food demand. Both food production and food demand are affected by prices. Household prices are endogenous in order to account for the existence of transaction costs that impact farmer's decisions on their market participation. Production prices are a function of international markets and trade, infrastructure and market efficiency. In sum, FSSIM-Dev is a comparative static and non-linear optimisation model which relies on both the general household's utility framework and the farm's production technical constraints, in a non-separable regime. Consequently, it maximises farm household income subject to resource constraints (includes land and labour), cash, market clearing conditions, linear expenditure system (LES), price bands and complementary slackness conditions.

The general mathematical formulation of the model is the following:

Max U = $\sum_h w_h R_h$

S.t.:

- Resource constraints
- Linear expenditure system (LES)
- Price bands & complementary slackness conditions
- Market clearing conditions
- Cash constraint

where **U** is the value of the objective function, **h** denotes a farm household and **w** its weight within the village, region or country and **R** is the farm household expected income. For more details on the mathematical structure of the model and its functioning, see Louhichi & Gomez-y-Paloma (2014).

Farm household income (R) is defined as the income earned from all economic activities of family members of the same household. It is composed of three components: agricultural income, income from marketed factors of production (non-farm wages, rent of land and equipment) and off-agricultural incomes. Agricultural (farm) income is defined as the income earned by households from selling or consuming their own agricultural products. Off-farm incomes are defined exogenously and can originate from different sources such as non-farm wages, self-employed activities (petty trading, craftsmanship, etc.), pensions, transfers (including remittances) and donations.

Agricultural (farm) income is computed as the sum of agricultural gross margin minus a non-linear (quadratic) activity-specific function. Gross margin is the total revenue from agricultural activities, including sales and self-consumption, minus the accounting variable costs of production activities. The accounting costs include costs of seeds, fertilizers, crop protection, and other specific costs. The quadratic activity-specific function is a behavioural function introduced to calibrate the farm model to an observed base year situation, as is usually done in Positive Mathematical Programming (PMP) models. The PMP methodology (Howitt, 1995), recently refined by Mérel and Bucaram (2010), intends to replicate households' production and consumption decisions in a precise way, allowing to capture the effects of factors that are not explicitly included in the model such as price expectation, risk-adverse behaviour, labour requirement, capital constraints and other unobserved costs (Heckelei, 2002). The principal outputs generated by FSSIM-Dev for a specific policy scenario are forecasts on resource use, agricultural production, food consumption, market factors exchange, farm household income and poverty level at farm household and aggregated levels.

For the present study, the consumption module of FSSIM-Dev was switched-off due to missing data on income elasticities. The supply module was implemented for the cropping season 2010/2011, corresponding to the period covered by the Niger LSMS-ISA survey. The model calibration was performed at the individual farm household level using the Highest Posterior Density (HPD) estimator with prior information on supply elasticities (Louhichi et al., 2015). Model parameters were calibrated so that the model exactly replicates an observed land allocation among irrigated and non-irrigated crops, as well as an exogenous set of supply elasticities. The calibration to the exogenous supply elasticities is performed in a non-myopic way, i.e. we take into account the effects of changing dual values on the simulation response

(Heckelei, 2002, Mérel and Bucaram, 2010). The parameters of the behavioural function are estimated only for observed activities in each farm household, meaning that the well-known self-selection problem is not explicitly handled in this estimation. To cope with this problem, we adopted the following ad-hoc modelling decisions in the simulation phase: in each region, the gross margin of the non-observed activities is equal to the farm-type average gross margin, the activity's quadratic function parameter is equal to the activity's average quadratic function parameter within the farm type, and the linear term's quadratic function is derived from the difference between the gross margin and the dual values of constraints.

3.2. The LSMS-ISA survey in Niger

The research described in this paper and the simulation exercise are based on the exploitation of the dataset of farm households originated by the 2011 Living Standard Measurement Survey – Integrated Survey of Agriculture (LSMS-ISA). This very comprehensive survey was conducted by the National Institute of Niger with the technical support of the World Bank. Data were collected in two waves, in order to cover both the off season (from Dec. 2010 to May 2011) and the rain-fed (June 2011 to Nov. 2011) cropping cycles. The full sample includes about 3,970 households, all involved in agriculture (including livestock) activities. Most of them are rural households. The survey sample was designed following a random two-stage process and was stratified by four agro-ecological areas, namely urban, agricultural, agro-pastoral and pastoral. The final sample is representative both at country and regional level, for urban and rural areas. Three different questionnaires were used, at different level of data collection: at community level, at household level, and the last one specific to agricultural activities.

The Niger 2011 LSMS-ISA survey featured many different modules, which could be roughly gathered around three topics: (1) household activities, consumption and livelihood, (2) agricultural activities and (3) livestock activities.

(1) Data were collected in order to trace all the food and non-food expenses of the households. A seven-day recall methodology was used to collect data on food consumption. All non-farm activities, as well as any source of income, are reported, for any member of the household.

(2) Data on agricultural activities include a comprehensive description of all fields of the farm, land tenure, type of soil and available infrastructure (anti-erosion, irrigation,…). Production cost (labour and input) are collected at plot level. The quantity of family labour, labour exchange and hired labour used for each crop and for different farming operations is also available. Crop output is collected for each plot and each crop on the plot. Plot size was measured by GPS, at least in most of the cases.

(3) Data on livestock activities include a comprehensive description of all type of herds of animals owned by the farmers, the output (sales) and production costs.

The 2011 LSMS-ISA dataset was prepared for the purpose of this research. Variables such as crop yield, quantity of input used and prices were treated for outliers (using either Tukey's method based on Interquartile Range and trimmed mean) and missing values. However, the main limitation of this dataset is that, at the time of the data collection, the whole country suffered a severe drought that dramatically affected the rain-fed cropping season. Therefore, the yields calculated from the survey data are very low, especially for cereals such as millet and sorghum. As they do not correspond to the farmer's expectations when the take their planting decision, we have replaced those data by the expected yields, calculated notably using the estimation of losses by farmers.

For this research, we focused on those household with agricultural (crop) activities. This results in the exclusion of those households that are involved in cattle breeding only, but mix farms are included. The final size of our sample is therefore 2,322 households. The key features of the sample used for this research are presented in Table 1.

Table 1: Sample characteristics

Regions	Agadez	Diffa	Dosso	Maradi	Tahoua	Tillaberi	Zinder	Niamey	Niger
Number of surveyed farm household	108	227	389	389	378	374	384	73	2322
Total area covered (ha)	116	856	1167	803	863	2035	994	214	7048
Average farm size (ha)	1.1	3.8	3.0	2.1	2.3	5.4	2.6	2.9	3.0
St. Dev.	0.9	3.3	2.5	2.5	2.5	5.1	3.4	12.0	4.0
Number of farms with irrigation	89	53	37	7	54	41	20	46	347
Average irrigated land (ha)	0.9	2.1	0.6	0.2	1.0	1.7	2.3	3.2	1.5
Land use in rainy season (% by region)									
Millet	18.7	57.0	46.9	38.3	43.8	57.1	39.6	64.2	47.2
Sorghum	13.9	15.0	7.3	22.0	23.3	10.0	20.9		15.5
Paddy rice	16.4							6.0	0.6
Black eyed pea	4.4	10.1	28.3	33.1	26.4	21.6	30.7	22.9	25.6
Peanut		4.3	6.5		4.7				3.6
Onion	34.9								0.6
Land use in off-season (% by region)									
Paddy rice		15.7	28.6			48.6		19.3	16.9
Sweet Potato			27.3			19.8			5.1
Sweet Pepper		74.8					7.8		22.3
Chili				10.9		6.2	6.0		2.9
Cabbage				23.8	8.8		6.5	16.2	5.1
Tomato				10.1	6.3		8.3	20.1	6.5
Jaxatu							52.2		8.1
Onion	45.2			7.9	77.4	7.5			16.5
Pumpkin						7.9	5.2		2.4

4. Baseline and simulation of the effects of the SPIN

The baseline scenario is interpreted as a projection in time including the most probable future development in terms of technological, structural and market changes. It is used as a reference point for the comparison of the effects of the simulation scenario. In our case study, the baseline scenario is assumed to be similar to the baseyear which means that all model parameters are assumed to remain unchanged including output prices, yields, variables costs, implicit costs (i.e. PMP terms), farm resource endowments and farm weighting factors (no structural change). As in the baseyear, the exchange of production factors between farms is not allowed (i.e. there are no land or labour markets).

The policy scenario that is simulated for this study attempts to estimate the potential impacts of the implementation of the "strategy for small irrigation development in Niger" (SPIN in French) (Ministère de l'Agriculture, 2015). In concrete terms, we simulated an increased access to irrigated land for farmers in Niger and assess the potential impacts in terms of land use change, agricultural production and income change. This scenario will therefore enlighten the potential effects of the implementation of the SPIN for farm households in Niger. The objective of the SPIN is to increment the land area suitable for small irrigation by 152%, from the 107,000 hectares as currently to 270,000 hectares over the next teen years (see Table 2). The SPIN will finance projects of small irrigation development at the request of farmers, groups of farmers or local authorities. The SPIN considers two types of requests: the “social” one and the “normal” one. The first type targets specifically the most vulnerable farmers, either on economic or on climatic grounds. For those farmers, the project will be implemented at no cost, while for the other it will be partially subsidized and partially financed by credit. For this simulation exercise, we focused on the first type of request, because it is very much in line with the objective of strengthening the food security and alleviate poverty in Niger.

Therefore, we assumed that the cost of the investment (the implementation of the irrigation infrastructure) for those farmers benefiting from a small irrigation project will be zero, since the overwhelming majority of farmers in Niger could be considered marginal. However, all other costs linked to the farm operations on the “new” irrigated land, if any, including the costs specific to the irrigation systems, have to be supported by the farmers. In the simulated scenario, we have set for each region and farm a potential irrigated area that would correspond to the increase of irrigated land that is forecast by the SPIN, based on the potential irrigable land for each region of Niger. Therefore, all farms could potentially access to irrigated land, at no cost, and they will decide whether to use it based on the gross margin for irrigated crops in the region, their own factor endowment and cost structure. In this scenario, the adoption of irrigation is therefore only based on economic considerations, in a broad sense (there is not “technical infeasibility” of irrigation in a strict sense but this should be reflected by high and prohibitive implicit costs).

Table 2: Small irrigation in Niger, current situation and estimated potential

Watershed	Region	Potential irrigable land (ha)	Irrigated land with modern water management (ha)	Other irrigated land (ha)
Niger River	Tillabéri, Dosso, Niamey	144,000	9,233	
Dallols-Adder-Doutchi-Maggia	Tahoua	69,000	3,592	
Goulbis-Tarka	Maradi, Tahoua	17,000	570	93,150
Korama-Damagaram-Mounio	Zinder	10,000		
Manga	Diffa	20,000	295	
Aïr-Azaouagh	Agadez	10,000		
Total Niger		**270,000**	**13,850**	**93,150**

Source: Ministère de l'Agriculture (2015, 2012)

Based on these assumptions, the expected results of the simulation scenario would be: (i) an increase in the irrigated land at national and regional level; (ii) a switch in the overall pattern of cultivated crops in favour of irrigated ones (for instance, vegetable production); (iii) an increase of household income.

5. Results and discussion

We present here the impacts of the simulation scenario on a set of indicators generated from FSSIM-Dev at farm level, subsequently aggregated at region or country level. These indicators are: land allocation among irrigated and rain-fed crops, crop area and agricultural income. The results are generally expressed in relative change compared to the baseline.

5.1. Irrigated area by region

We simulated the possibility for every farm to access to irrigated land, with an upper bound corresponding to the potential irrigated area for each region, as indicated in the SPIN strategy documents. Therefore, the question is, will farmers use this possibility, and if they do, to which extent? Figure 1 provides a summary of the results of the simulated policy scenario. As expected, the irrigated area in Niger would dramatically increase. During the dry season, the irrigated area would increase by 208%, while during the rainy season it would be multiplied by 6. However, this increase has different explanations depending on the season considered. During the rainy season, farmers substitute rain-fed crops by irrigated ones which are much more profitable. Therefore, the total cultivated area remains the same in most of the country, but the share of irrigated crops in total land expands from 1% to almost 6%. In contrary, the extension of irrigated land during the dry season is achieved by enlarging the total cultivated area, from 2.4% of the total agricultural land to 7.3%.

Overall, the improved access to small irrigation would lead to an increase of the total cropped area in Niger by about 5%. The trend described above for the entire country also applies to every region in Niger, but in different proportions. The largest increase of total cultivated area would occur in Diffa (+22%) while there would be a contraction of 4.1% in the Niamey region (the only region to actually decrease). The largest increase of irrigated area during the dry season is observed in the Zinder, Dosso and Tahoua regions, with a relative change to the baseline of 260%, 219% and 213%, respectively. In these regions, the production of off-season vegetables is already quite important. The increase of irrigated land in relative terms is much higher during the rainy season, but this is also explained by the small irrigated area during this season in the baseline. In absolute terms, the Tillabéri region would remain the first region for irrigated area (for both seasons), followed by Tahoua and Zinder.

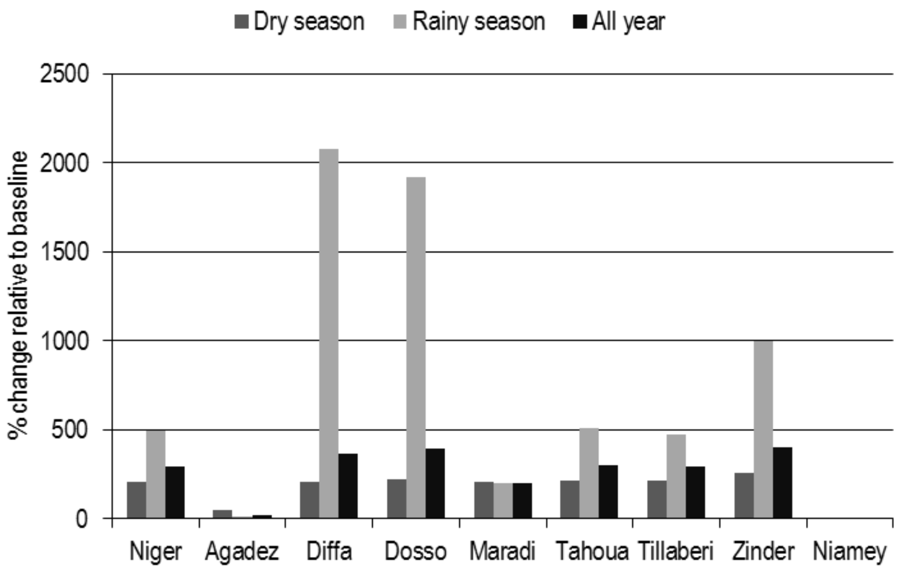

Figure 1: Use of irrigated land area under the simulation scenario (relative change compared to the baseline – population weighted)

At individual farm level, the results of the simulated policy scenario show that approx. 83% of the farmers in Niger would engage in irrigation if they were given the possibility to do so. Also, the mean increase of irrigated area would be of 0.56 hectare for the entire country, while only 16.7% of the farmers would actually increase their irrigated area by more than 1 hectare. Figure 2 displays the distribution of this increase irrigated area for the whole sample of farmers.

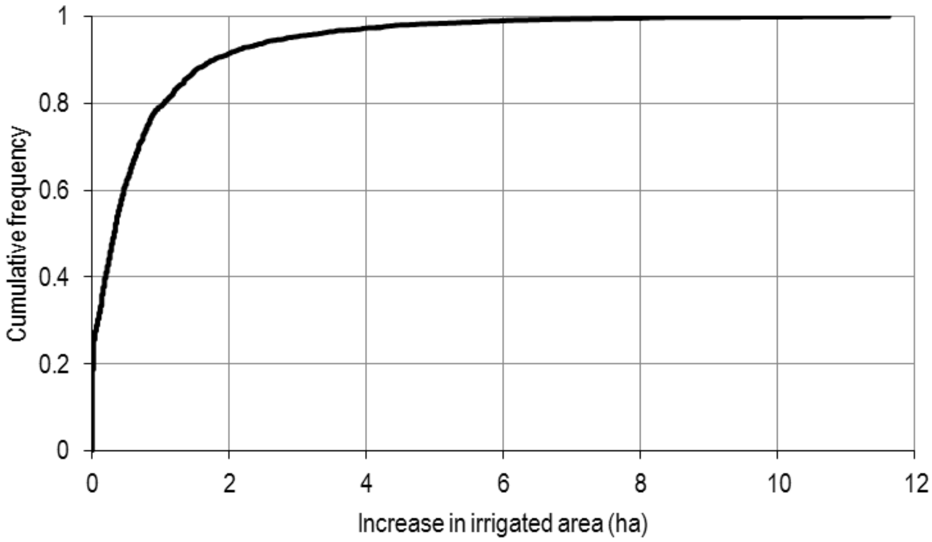

Figure 2: Cumulative distribution of the absolute change of irrigated area

5.2. Crop land use

A closer look to the relative change of area cultivated by crop gives a better insight of the choices made by farmers when they are given access to irrigated land. In fact, the most important changes in land use are occurring for the dry season, which makes sense since by definition, access to irrigation makes it possible to develop cropping activities that previously were impossible during this season. However, as the total area cultivated during the off-season is still far from the area cultivated during the rainy, the impact of this change on the land use over the full year rather limited (see Figure 3a). Millet, black-eyed pea and sorghum remain the three most important crops in terms of cultivated area, although there cumulated proportion of the total cultivated area slightly decline from 88% to 82%. On the contrary, paddy rice area is growing significantly, and its share of the total cultivated area increases from less than 1% to about 3.5%. Cassava and peanut crop are also following the same trend but to a lower extent.

At the regional level, the changes tend to be more marked. For instance, the production of staple crops (millet, sorghum and black-eyed pea) would shrink at a higher level in Diffa and Niamey region, while there would be no change in Maradi. Rice production expansion is occurring mainly in Diffa, Dosso and Tillabéri.

Focusing on the changes occurring during the off-season for land use reveals other patterns of changes (see Figure 3b). It shows that the extended access to irrigation would make paddy rice the first crop during this season instead of onion. Although onion cultivation would increase by 168% during the dry season, its share of the total cultivated area would decline from 25.7% to 22.4%. On the contrary, paddy rice would represent more than one third of the total area cultivated during the dry season. Other crops that would lose importance are sweet pepper, sweet potatoes, pumpkin, cabbage, sugar cane, or carrots. On the other hand, eggplant, cassava, tomato and lettuce would represent a larger share of the total cultivated area during the dry season. The largest increase of cultivated area in relative terms (compared to the baseline) would be observed for cassava, paddy rice and okra, in this order.

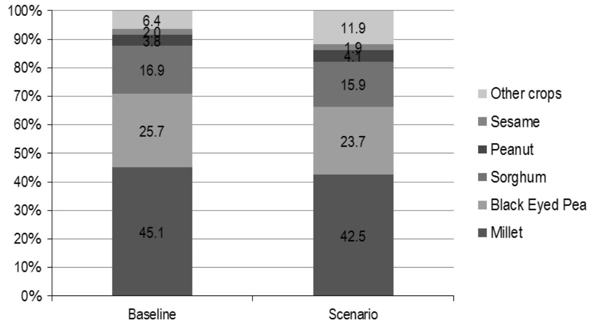

Figure 3a: Crop land use in Niger over one entire year

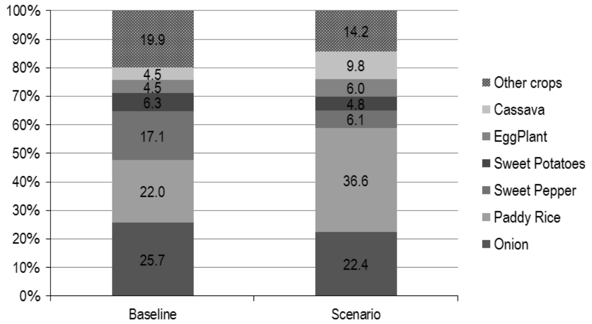

Figure 3b: Crop land use in Niger over the dry season

5.3. Agricultural income

The economic impacts of the increased access to irrigation are assessed in two ways: at country and regional aggregate level and in terms of income change by income decile. As expected, access to small irrigation would increase agricultural income by around 7% at country level. The largest increase is observed in Diffa, while there is virtually no effect in Maradi and Niamey. As shown in Figure 4, most of the changes in agricultural income are driven by the reallocation of land during the dry season, that is to say the extension of irrigated area. However, the region where agricultural income has the greatest increase are not necessary those where the irrigated land expands the most. This is because the kind of agricultural production that is available to farmers also matters. Some crops are more profitable than others. To this respect, paddy rice plays an important role in the large income increase in Diffa for instance.

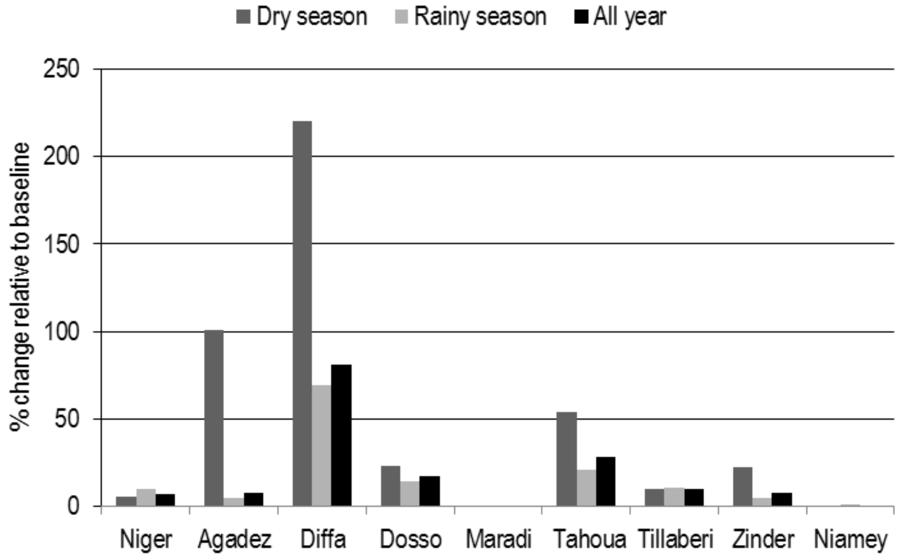

Figure 4: Agricultural income under the simulation scenario (relative change to baseline – population weighted)

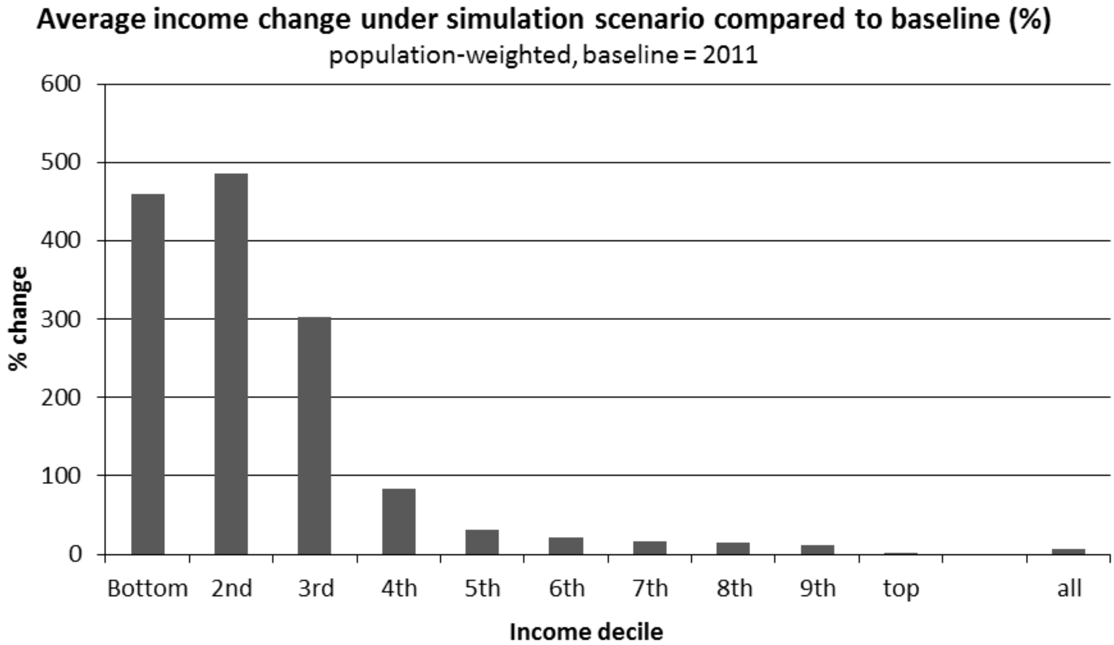

Figure 5: Agriculture income change by income decile (relative change to baseline)

Figure 5 shows how the benefits of the enlarged access to small irrigation would be distributed among the different categories of income. The big picture is that this policy would have a clear effect in terms of closing the inequality gap among farm households in Niger.

Indeed, the largest income increase would be obtained by the poorest households. This is explained by the very low agricultural income that households with poor endowment in land and capital are getting in the baseline. Those household typically derived their agricultural income from traditional cropping system of millet, sorghum, and possible black-eyed pea, with low yield and low income. If these households are given the possibility to practice off-season, irrigated agriculture, they would therefore benefit from the high-value added of vegetable crops or other more diversified staple crops.

6. Limits of the approach and conclusion

This paper attempts to *ex-ante* assess the impacts of small irrigation scheme on the livelihood of smallholder farms in Niger and on their food security. This is performed using a micro-simulation model, named FSSIM-Dev (Farm System Simulator for Developing Countries). FSSIM-Dev is a static positive programming model that is applied to every individual farm household of a sample of 2,300 farm households drawn from the 2011 LSMS-ISA survey. This allows to capture the full heterogeneity across farm households and to get results of the simulation at individual farm level.

From a policy perspective, the main finding of this model application is the large effect of small irrigation program on crop allocation, production and farm income. The total cropped area would increase by 5% in Niger, representing a positive impact for the availability of food and therefore to food security. The cultivated area of paddy rice and cassava, two staple crops with an important role in the diet of farm household, would notable see a dramatic increase. Agricultural income at national level would increase by around 7%. At the regional levels the impact would be even more pronounced (reaching more than 15 % in three regions), while at individual level, about 20% of farm household would get an increase higher than 100% (accounting for household weighting factors). Finally, an important contribution of irrigation to food security, that is not accounted here, is the stabilization of crop yields. Irrigated crops are generally less susceptible to drought than rain-fed production, in the short run.

These findings have to be considered, however, with some caution on account of the model's assumptions. First of all, output prices are assumed to be exogenously given. This implies that the market feedback (output price changes) is not taken into account in the model, while this effect tends to be important in developing countries in general, and in Niger in particular, where high transaction costs tend to isolate the various local market from each other, hampering price transmission. This issue is even more acute for vegetable crops that are less easy to transport than cereals for instance. Therefore, our model will probably overestimate the overall effects of the simulated scenario.

Another important limitation to our approach is that there are other constraints to the extension of irrigated production that are not taken into account here, such as the soil type or water management at community level. The commercialization of vegetable crop is another issue, and in reality vegetable production tend to develop near city centres where some demand exists.

Despite these limitations, the simulation results presented here can be useful to policy makers that are currently developing small irrigation support programs in Sub-Saharan African countries. Further development of the FSSIM-Dev model will better take into account the above-mentioned limitations.

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