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Impacts of Small-Scale irrigation in Niger

Ex-ante analysis of micro-economic effects using a farm household model

Tillie, P., Louhichi, K. and Gomez-Y-Paloma, S.

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IMPACTS OF SMALL-SCALE IRRIGATION IN NIGER

Ex-ante analysis of micro-economic effects using a farm household model

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Abstract

In Niger, one of the key objectives of agricultural policy is to promote the development of small-scale irrigation infrastructure in order to diversify agricultural production, extend the growing season, increase land productivity and secure farmers' incomes. Small-scale irrigation is regarded as a possible alternative to large-scale collective schemes because it is cheaper to set up and maintain and easier to manage. This report presents the results of modelling the impacts of a small-scale irrigation development programme, known as the *Stratégie pour la Petite Irrigation au Niger* (Small-Scale Irrigation Strategy in Niger, or SPIN for its acronym in French), in terms of land use, agricultural production, income generation and poverty reduction. This analysis was conducted using the FSSIM-Dev (Farm System Simulator for Developing Countries) model and data obtained from a representative national sample of farm households. FSSIM-Dev is a comparative static model using a positive mathematical programming (PMP) approach tailored to producer-consumer households and to the particular aspects of the sub-Saharan rural economy. Applied to each farm household included in a representative sample for Niger, FSSIM-Dev allows for capturing all the heterogeneous impacts of a development programme such as the SPIN. The modelling results show that increasing the irrigated area in the dry season by 47,000 hectares, i.e. 44%, which is in line with the SPIN objectives, would bring significant benefits to Nigerien farm households. The average farm income would increase by 12% and income inequalities between households in rural areas would reduce by around five Gini points, i.e. approximately 9%. Increasing the irrigated area would also create many new jobs and reduce the rural poverty rate by more than one point (from 52.4% to 50.8%). The estimated cost of such a programme would be between 47 billion CFA francs and 189 billion CFA francs, to be split between farmers and the State.

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Foreword

The Joint Research Centre (JRC) is one of the directorates-general of the European Commission. It comprises seven research institutes located in five EU Member States (Belgium, Germany, Italy, the Netherlands and Spain). Its mission is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies (including international technical cooperation measures).

Since 2014, the JRC has been working with the Directorate-General for International Cooperation and Development (DG DEVCO) on a project entitled 'Technical and scientific support for agriculture and food and nutrition security sectors' (TS4FNS) in sub-Saharan Africa. The main aims of this project are to (i) improve existing information systems on agriculture, nutrition and food security, (ii) conduct economic analyses aimed at guiding decision-making on agricultural and cooperation policies, and (iii) provide scientific advice on specific issues concerning sustainable agriculture and food and nutrition security.

One of the main activities within the project's economic axe involves assessing the impact of agricultural and cooperation policies at the micro- and macro-economic levels. This work relies on the development of models tailored to the specific economic conditions of the countries of sub-Saharan Africa. For example, at the micro-economic level, these models allow for the estimation of the effects of input subsidy programmes on poverty and income inequalities, whilst, at the macro-economic level, they make it possible to analyse the impacts of a change in customs barriers on agricultural production and the trade balance. The aim is twofold: to provide DG DEVCO and European Union Delegations with analyses of the impacts of cooperation programmes and development policies, and to support local authorities in their reflections on how to implement their agricultural policies.

1 Introduction

In 2015, Niger was ranked 187th out of 188 in the Human Development Index (HDI) of the United Nations Development Programme (UNDP), making it one of the least developed countries in the world (UNDP, 2016). In 2016, Niger's population was around 20.7 million, with over 80% living in rural areas and 75% having less than USD 2 per day. However, the extreme poverty rate has fallen in recent decades, from 63% in 1990 to 48% in 2011. GDP per inhabitant increased by nearly 75% between 2000 and 2014, to around USD 427 per inhabitant. The agriculture, forestry, livestock and fish sectors have always dominated the national economy (nearly 45.2% of GDP in 2010) and employ over 80% of the working population (Banque Mondiale, 2018; HCi3N, 2012).

Population growth is one of the most striking aspects of Niger's economy. According to UN figures, the annual population growth rate was 4% on average over the 2011-2015 period, putting the country in third place globally. This strong population growth has major consequences in terms of population density in rural areas. It both increases the pressure on land in existing agricultural areas and contributes to the extension of agricultural limits beyond the most suitable land, particularly in the Sahelian zone. Between 1980 and 2012, the ratio of arable land per agricultural worker therefore fell from 11.8 hectares to 1.1 hectares (INS, 2012). This generally results in a shorter fallow period being included in crop rotations, an overexploitation of land that is already particularly vulnerable to erosion and a loss of nutrients. This increased pressure on the land therefore has not only direct agronomic consequences (acceleration of the sometimes irreversible degradation of soil), but also social consequences because it tends to exacerbate conflicts between the different categories of land user, mainly between farmers and livestock breeders.

Despite the constraints on the agricultural sector in Niger, its development is vital to meet the growing food demand of the rural and urban populations and to achieve both economic growth and poverty reduction objectives. Niger's Economic and Social Development Plan (*Plan de Développement Economique et Social* – PDES 2012-2015 and then PDES 2017-2021), which sets the political priorities of the Niger government, highlights the need to improve food security and implement sustainable agricultural development. The 3N Initiative (*Initiative 3N,* the French acronym of the sentence *'Les Nigériens Nourrissent les Nigériens'* i.e. Nigeriens Nourishing Nigeriens) is the flagship element of Niger's agricultural policy and the operational link of the PDES in terms of rural development. Among all the activities identified by the 3N Initiative investment plan, some are being taken forward, such as land recovery, development of irrigation and provision of extension (or farm advisory) and technical assistance services to farmers.

The aim is to halt the degradation of land exacerbated by climate change and increase agricultural productivity by using more inputs, in particular fertilisers. The development of irrigation infrastructure should also help to increase yields and secure farmers' income, while allowing cropping systems to be diversified. Furthermore, the 3N Initiative also represents a break with the past due to the importance placed on the development of small-scale irrigation, whereas previously, priority was generally given to constructing collective infrastructures such as large-scale irrigated areas.

It is in this spirit that the Ministry of Agriculture and Livestock has also formulated a specific strategy for developing this irrigation sub-sector, known as the Small-Scale Irrigation Strategy in Niger (*Stratégie pour la Petite Irrigation au Niger* – SPIN). SPIN aims, on the one hand, to meet the harmonisation needs of intervention and funding approaches in the area of small-scale irrigation (SSI) and, on the other hand, to encourage the emergence of a decentralised mechanism for developing sustainable small-scale irrigation based on user (farmer) demand and the participation of the private banking sector.

This report aims to present the results of an ex-ante assessment of the potential impacts of developing small-scale irrigation infrastructures in Niger, using a micro-economic model allowing for the simulation of the behaviour of Nigerien farm households. These impacts are measured in terms of allocation of irrigated land, production and farm income, and the modelling uses data collected in 2011 from a representative sample of 2,322 Nigerien farm households.

2 Agricultural development and small-scale irrigation in Niger

2.1 Opportunities and constraints of small-scale irrigation in sub-Saharan Africa

A number of studies have detailed the advantages of small-scale irrigation infrastructure for small agricultural holdings in sub-Saharan Africa, and its potential to increase irrigated areas, combat poverty and improve the food security of rural households. Small-scale irrigation is defined as the supply of water to small plots, which is controlled by producers themselves, using techniques that farmers can easily master and maintain (Carter, 1989). It is precisely the simplicity of these irrigation systems that attracts small-scale farmers in sub-Saharan Africa, as they generally involve limited set-up costs. Furthermore, access to irrigation often represents an important turning point in the path of agricultural holdings, which can move from subsistence farming to commercial farming (Purcell, 1997).

The first advantage of small-scale irrigation is therefore its relatively low investment cost. A study conducted in Niger in the 1990s showed that a small-scale irrigation infrastructure involving a motorised pump and plastic pipes could be set up for less than USD 2,000 per hectare, compared with between USD 10,000 and USD 25,000 for a large-scale irrigated area with complete control of the irrigation and water level (Gay, 1994). Furthermore, whilst large-scale irrigated areas are sometimes reserved for rice farming, small-scale irrigation infrastructure tends to be used more for market gardening, with products destined for nearby urban centres. Small-scale producers in sub-Saharan Africa have more to gain from focusing on the production of fruit and vegetables with high added value than from trying to compete with foreign producers of rice or grain who are generally more competitive, except in the specific cases of isolated markets. In addition, the significant urbanisation of the region and the gradual emergence of a middle class assures them of strong growth in demand for market garden products in coming years (Perry, 1997). The second advantage of small-scale irrigation therefore lies in the earnings that small-scale producers can expect, in terms of net farm income, which are much greater than those obtained from rain-fed crops.

The main obstacles are funding and marketing. Funding of the investment and production, although modest, continues to represent a constraint for many small-scale producers who generally do not have access to formal credit due to a lack of security or collateral. The difficulties generally associated with marketing are high transaction costs, information asymmetries, an oligopsonistic organisation of fruit and vegetable buying markets and a significant risk due to high price volatility.

However, despite these obstacles, many studies have recently shown the benefits of small-scale irrigation for small farm households. In Ghana, a project to promote small foot pumps increased the irrigated area for a quarter of beneficiaries, improved the labour productivity of all beneficiaries and increased average income per hectare by nearly USD 400 (Adeoti et al., 2007). A comparative study conducted in Mali also revealed that small irrigated areas have a positive effect on agricultural production that is nearly twice that of larger areas, as well as a greater effect on income (Dillon, 2011). In addition, access to irrigation also reduces the risks inherent in climate variability, and helps to create jobs in the rural environment (Giordano et de Fraiture, 2014; Takeshima et Yamauchi, 2012; Tesfaye et al., 2008). Some authors note, however, the existence of increased risks associated with the lack of infrastructure, overexploitation of watercourses or aquifers, degradation or salinization of soil, and also market volatility (Burney et Naylor, 2012; de Fraiture et Giordano, 2014).

2.2 Small-scale irrigation in Niger

2.2.1 Agricultural constraints in Niger and the potential of small-scale irrigation

In Niger, agricultural production faces very hostile conditions due to the country's arid climate, characterised by low rainfall, a short rainy season and high temperatures. Despite these constraints, agriculture remains the most important sector in the Nigerien economy, both socially and economically. Its contribution to GDP, in 2010, was estimated to be around 45% and the sector employs over three-quarters of the working population (INS, 2012). It is also the second most important sector in the economy, after mining, in terms of contribution to export revenue, mainly due to the export of live animals and agricultural products such as onions or sesame to neighbouring countries (Ministère de l'Agriculture, 2014). In the last 10 years, the agricultural sector has developed much faster than other sectors of the economy.

Most Nigerien agricultural production revolves around small family holdings, generally with less than 2 hectares. The traditional farming systems are based on the rain-fed cultivation of grain, mainly millet and sorghum, mostly using cropping systems that involve legumes such as groundnuts or cowpeas (a cultivar of the species *Vigna unguiculata*). Where they have access to irrigation, farmers generally add market garden products to the above crops, mainly onions, sweet peppers, lettuce, tomatoes or aubergines. Overall, irrigated crops account for 30% of the added value of agricultural production and 90% of agricultural exports (except for livestock products) (FIDA, 2012).

In addition to the agricultural and climate constraints facing agricultural production in Niger, there are other barriers that could be more easily lifted. Most farmers still have a limited access to the majority of production factors (inputs and agricultural equipment) and extension services. Access to markets is also hindered by an under-developed road network and transport infrastructures. Access to credit remains very difficult for farmers.

Lastly, Niger is also in the front line in terms of the potential negative impacts of climate change. The country is particularly vulnerable to soil degradation and desertification in general. It could suffer significant falls in grain yields if farming systems are not adapted to the changing climate conditions, in particular the shortening of the rainy season. Due to the high proportion of grain (millet, sorghum) in the food of most farm households, the consequences for food security and population nutrition could be very damaging.

Most of the land cultivated in Niger lies in the Sahelian-Sudanian climate zone, which receives between 300 mm and 600 mm of rain per year, from June to September. This quantity of water, although limited, could be better exploited for agricultural production if an appropriate technique or infrastructure were used to prevent water runoff or infiltration and to retain as much water as possible. In addition, the water resources of the main watersheds in Niger – Niger River and Lake Chad – are not fully exploited. Lastly, the underground water resources in Niger, which have long been estimated at around 270,000 hectares (*Ministère de l'Agriculture*, 2015b), have recently been largely reassessed. According to a MAGEL study, the irrigable potential of Niger is in fact over 10 million hectares, including around 5.7 million hectares where the water table is lying at a depth of between 0 metres and 15 metres, i.e. suitable for small-scale irrigation (*Ministère de l'Agriculture*, 2015a). Currently only 93,000 hectares are less than perfectly exploited for small-scale irrigation (*Ministère de l'Agriculture*, 2015b).

Consequently, the challenge for agriculture in Niger is therefore to better manage the water supply and soil fertility, and to do so in a sustainable manner. Grain and vegetable yields could be increased and their variability reduced by using improved varieties, adopting anti-erosion techniques, using more animal traction for farming operations or introducing agro-ecological innovations. Improved exploitation of rainwater and better management of irrigation systems to improve the effectiveness of water also represent an important lever for developing agricultural production in Niger. Improving and stabilising agricultural yields would also allow farm households to meet their subsistence needs and generate a surplus to sell. This would also strengthen their resilience to climate change.

The development of irrigation therefore represents an important lever for increasing agricultural production in Niger.

2.2.2 The Small-Scale Irrigation Strategy in Niger

In order to support the development of its agricultural sector, in 2012 Niger adopted a common framework for all rural and agricultural policies, called the '3N Initiative', which stands for 'Nigeriens Nourishing Nigeriens'. The main objective of this initiative, and its new acceleration plan adopted in 2014, is to encourage the domestic production of foodstuffs in order to strengthen the country's supply and its resilience to food crises and natural disasters (HCi3N, 2012). The 3N Initiative has the merit of having correctly identified a large number of the constraints facing Nigerien agriculture. One of its goal is to overcome some of the market imperfections by establishing a network of village shops, known as *maison du paysan*, where farmers should be able to find inputs, farm advisory services, agricultural tool repair workshops and even micro-credit facilities.

One of the main focuses of the 3N Initiative is the development of small-scale irrigation, i.e. irrigation of a small area belonging to a farmer, a community of farmers or a village. The importance placed on small-scale irrigation in Niger stems from a number of findings. First of all, grain yields in Niger have fallen in recent decades due to various factors such as soil degradation, shortening or disappearance of fallow periods between growing periods, and increased pressure from pests (such as the millet borer or the crickets that ravage millet, sorghum and rice). Irrigated crops such as legume production are therefore regarded as an alternative to grain in terms of income generation. Legume production is generally associated with food diversification and therefore improved household nutrition. Second, irrigation can stabilise yields in the face of varying rainfall and it can virtually extend the cultivated area by allowing the use of land during both the dry and rainy seasons or by allowing the cultivation of land that cannot be used during the dry season (for example in the bed of a temporary watercourse where a shallow depth of water remains during the dry season, which can be utilised using a pump). Lastly, small-scale irrigation is also regarded as a viable alternative to the large water irrigated perimeters, which were preferentially set up until the late 1990s but turned out to be very difficult to manage in a cost-effective manner (*Ministère de l'Agriculture*, 2015b).

The above factors have therefore led the Ministry of Agriculture to formulate a specific strategy for the development of small-scale irrigation, in the context of the 3N Initiative, namely the *Stratégie pour le Petite Irrigation au Niger* or SPIN (*Ministère de l'Agriculture*, 2015b). The overall aim of the SPIN is to increase the area that is effectively irrigated and therefore the resulting production in order to ultimately improve food and nutritional security in Niger, stimulate agricultural productivity and increase the resilience of rural households to climate variations. In particular, through this strategy, the government body in charge of the 3N Initiative, the *Haut Commissariat à l'Initiative 3N* will support small irrigation projects proposed by local authorities, villages or groups of farmers in exchange for a financial or physical contribution (work) from beneficiaries. Small-scale irrigation infrastructures have the advantage of being flexible and easily adapted to a range of situations and water sources (surface water, groundwater, rainfall). The most common types of small-scale irrigation infrastructure that the SPIN intends to develop are: shallow wells and boreholes (depth of less than 15 m) with pumps, creation of agricultural retention pounds, small hill reservoirs, river weirs, small pumping stations in permanent watercourses, etc. (see **Box 1**).

Box 1: Various types of Small-Scale Irrigation in Niger

- Gravity-fed irrigation from a concrete well in the Tadis valley (Tahoua region):

- Sorey water-spreading weir and associated market garden production (Niamey region):

- Traditional well and market garden production in Yaixlaré (Dosso region):

- Small-Scale Irrigation using a pump in the Niger river in Gabougoma (Niamey region):

SPIN partly stems from the finding that a number of previous approaches, which also aimed to increase the irrigated area in Niger, failed to some degree in providing the full range of expected results. These approaches were generally based on a significant commitment by the State, who built collective irrigated perimeters and made them available to a group of producers. However, these highly centralised experiments did not always produce the expected results, particularly in periods when the State, due to a lack of resources, was unable to ensure that maintenance and upkeep activities were continued. The collective management of these areas was also prone to problems, particularly as producers were not always sufficiently trained to irrigation techniques in advance. Low yields and land issues or disputes during the distribution of plots were other problems encountered in these collective approaches (*Ministère de l'Agriculture*, 2015b). Due to the management and cost-effectiveness issues encountered with these large-scale irrigation schemes, both the Nigerien authorities and donors started to pay more attention to small-scale irrigation from the 1990s.

As a result, between 1994 and 2012, nearly 14,000 hectares of new irrigable areas were provided with small-scale irrigation systems using different methods: capture from rivers, concrete or artesian wells, infrastructure development alongside rice irrigated perimeters, water-spreading weirs, etc. These developments were mostly carried out privately, with support from a development programme such as the World Bank's Private Irrigation Promotion Project (*Projet de Promotion de l'Irrigation Privée* – PPIP). Since 1996, the Niger government has supported the growth of private small-scale irrigation and encouraged the establishment of a private agency of irrigation professionals, the ANPIP (*Agence Nationale de Promotion de l'Irrigation Privée*).

In addition to providing support to holdings so that they could benefit from a small irrigated area, these projects particularly helped to lay the foundations for the future development of small-scale irrigation in Niger. They allowed the institutional foundations for the growth of the sector to be established and enabled the acquisition of the technologies and know-how needed not only by farmers but also stakeholders in the sector. They encouraged a change in the traditional production and cropping systems and enabled the dissemination of high-productivity technological packages due to the development of extension services. Lastly, these initiatives also encouraged the emergence of local entrepreneurship among small-scale drillers, well-diggers and pump manufacturers and repairers. Finally, the resulting irrigated areas enabled development operators to compare the cost-effectiveness of irrigation models and identify those allowing the maximum profit to be gained from the investments made (*Ministère de l'Agricultur*e, 2015b).

All these observations and lessons therefore proved particularly useful when it came to designing SPIN as part of the 3N Initiative. Furthermore, a number of prior diagnoses were made in order to quantify the physical, human and economic potential of Niger in terms of small-scale irrigation. These particularly involved measuring the available land and water resources suited to implementing a small-scale irrigation scheme (which excludes deep boreholes for example). As a result, Niger's potential in terms of irrigable land has been estimated on several occasions. The most conservative estimate, which only includes areas with easily accessible water resources (water table at less than 15 metres, rivers, ponds, artificial dams, shallows, etc.), puts this potential at around 270,000 hectares (*Ministère de l'Agriculture*, 2015b), whilst the most optimistic estimates point to 5.7 million hectares or even 10 million hectares, depending on the respective depth of the water table (*Ministère de l'Agriculture*, 2015a). In any event, only a small proportion of this potential irrigable land is currently being used (see Table 1).

Table 1. Irrigation in Niger: situation in 2012 and potential irrigable land

<table>
<tr><th>Catchment area or watershed</th><th>Region</th><th>Irrigable potential (ha)</th><th>Area equipped as a collective irrigation perimeter in 2012 (ha)</th><th>Area equipped for small-scale irrigation in 2012 (ha)</th></tr>
<tr><td>Niger River</td><td>Tillabéri, Dosso, Niamey</td><td>144,000</td><td>9,233</td><td rowspan="6">93,150</td></tr>
<tr><td>Dallols-Adder-Doutchi-Maggia</td><td>Tahoua</td><td>69,000</td><td>3,592</td></tr>
<tr><td>Goulbis-Tarka</td><td>Maradi, Tahoua</td><td>17,000</td><td>570</td></tr>
<tr><td>Korama-Damagaram-Mounio</td><td>Zinder</td><td>10,000</td><td></td></tr>
<tr><td>Manga</td><td>Diffa</td><td>20,000</td><td>295</td></tr>
<tr><td>Aïr-Azaouagh</td><td>Agadez</td><td>10,000</td><td></td></tr>
<tr><td>Total for Niger</td><td></td><td>270,000</td><td>13,850</td><td>93,150</td></tr>
</table>

Source: *Evaluation du Potentiel en terre irrigable au Niger* (Assessment of potential irrigable land in Niger) (*Ministère de l'Agriculture*, 2015b).

The aim of the SPIN is therefore to increase the area of irrigated land in Niger using a number of principles that stem from the successes and failures of the earlier initiatives. These guiding principles are as follows (*Ministère de l'Agriculture*, 2015b):

- The main target of the SPIN is a farmer or a group of farmers.
- The SPIN encourages and supports producers who ask for help. The aim is therefore to ensure that the support provided genuinely meets a need and that the farmer asking for support is highly motivated to implement the investment. A financial contribution is also requested from the farmer, which varies depending on the type of support requested and the farmer's capacity.
- Viability and sustainability of the investments. In theory these are assessed by the financial institution funding the operation, supported by the extension and advisory services.
- The SPIN should be implemented in a decentralised manner, with a central role for the municipalities in terms of identifying and supporting beneficiaries.

Furthermore, there are two types of application in terms of the funding methods: the 'social demand' and the 'normal demand'. The first type specifically targets the most vulnerable farmers, whether this is for economic or climate reasons. For these farmers, the project is highly subsidised, up to 90% or even 100% depending on the project. For households making a 'normal' application, the funding split is as follows: for a maximum investment of 15 million CFA francs (which results on average in an irrigated area of 5 hectares), 10% is funded by the farmer at the start of the project, 40% is received in the form of a subsidy and the remaining 50% is financed by a bank loan.

The SPIN officially began in 2016 and is set to continue for a period of 10 years. Between 2016 and 2019, 3,450 hectares of land were already equipped with small irrigation. It is planned that the rate of development will accelerate so that there will be 21,000 hectares of newly irrigated land by 2021, added to which there is a plan to restore 500 hectares of previously irrigated land per year (Secrétariat Permanent SPIN, 2019). In summary, the ambition of the Ministry of Agriculture and Livestock is to increase the area with small-scale irrigation by 47,000 hectares by 2025, i.e.:

- 4,200 hectares of newly irrigated land per year;
- 500 hectares of previously irrigated land in poor condition to be restored per year.

The aim of this work is therefore to estimate the effects that increasing the area of small-scale irrigation may have on Nigerien farm households. This is an ex-ante assessment, which means that these effects are being estimated in advance, before SPIN has been fully implemented, in order to inform political decision-makers or any interested stakeholders about the policy's expected impacts.

3 Study methodology: FSSIM-Dev data and model

3.1 Modelling agricultural policies to better inform decision-makers

Measuring the impact of agricultural policies on poverty and food security is a complex subject due to the multiple dimensions of these phenomena. Food security is generally divided into several dimensions : food availability, access to food, use and stability. A range of qualitative and quantitative approaches have been developed to assess and/or demonstrate the impact of policies and technologies on food security both at the micro-economic and macro-economic levels. For example, food availability has been estimated using econometric techniques (Feleke et al., 2005; Larochelle et Alwang, 2014; Oluyole et al., 2009) and also empirical techniques involving specific surveys based on indicators such as availability of food calories within a household or, conversely, based on household expenditure.

Farm-household models have also been used to assess, at the micro-economic level, the impacts of policies and market forces on food security and poverty reduction, particularly in developing economies. Farm household models are well suited to take account of the particular aspects of rural economies in low-income countries where production, consumption and labour allocation decisions are non-separable due to market imperfections (De Janvry et al., 1991; Singh et al., 1986). These models are also capable of predicting the effects of transaction costs on market participation decisions. In summary, farm household models form a useful tool for understanding the main characteristics of the agricultural sector in developing countries and for assessing the systemic effects of policies on agricultural systems. They can provide information on the use of resources, agricultural production, changes in crop rotation, food consumption, participation in input and factor markets, agricultural and domestic income, level of poverty, etc. Farm household models are also important as they allow the impact of a measure on all holdings in a sample to be estimated, which therefore allows the analysis to determine how the effects are distributed across all holdings, and not just the average effects. A review of the literature for farm household models in developing countries (Louhichi et Gomez y Paloma, 2014) underlined the advantages and disadvantages of various methodologies, geographical coverage and behavioural assumptions used.

3.1.1 Overview of the FSSIM-Dev farm household model

In this study, we used the farm household model FSSIM-Dev (Farm System SIMulator for Developing Countries) (Louhichi et Gomez y Paloma, 2014) to assess ex ante the impacts on production systems, living conditions of farm households and food security of increasing irrigated area in Niger, as will intend to do the SPIN.

FSSIM-Dev is an economic tool for decision support intended to be used in the context of developing countries in order to improve knowledge on food security and poverty level in rural areas. It aims to inform policy decision-makers and development partners about how changes in prices, technology and agricultural and food policies can affect the food security and viability of farm households.

FSSIM-Dev is a household model. It means it is designed to analyse family farm holdings where production, consumption and labour allocation decisions are non-separable due to market imperfections. It provides a micro-economic picture of the farm household and therefore a detailed analysis of the effects of external shocks on the viability of farm households situated in various regions of the country. It is the results of the further development of the FSSIM farm model; developed as part of the European SEAMLESS project (van Ittersum et al., 2008) to analyse the impact of agricultural and environmental policies on the sustainability of production systems in Europe (Janssen et al., 2010; Louhichi et al., 2010).

The main advantage of the FSSIM-Dev model is its capacity to take account of the main characteristics of agriculture in developing countries, such as: (i) the non-separability of production and consumption decisions; (ii) the disparity between farm households in terms of their consumption baskets and resource endowments; (iii) the interdependence of transaction costs and market participation decisions, and (iv) the seasonality of agricultural activities and resource use.

FSSIM-Dev uses external prices to represent the supplies resulting from the main crop and animal activities in farm households. It simulates how a given scenario, for example a new agricultural policy, can affect a series of indicators, such as: crop mix, use of resources and inputs, crop and animal production, consumption, agricultural and household income, food and nutritional security of households, public expenditure and environmental externalities such as soil erosion and/or greenhouse gas emissions. These indicators can be aggregated and compared based on the type of farm holding, its technical orientation, economic dimension or region/village in which the household is located. These results cannot, however, be regarded as projections or predictions that are certain to come true, but rather as indications of trends prompted by the external shocks.

The main reason for developing this type of micro-economic tool is the significant disparity of agricultural policies in terms of both their implementation (i.e. policies are increasingly targeted and specific to certain categories of the agricultural population) and impacts. Farmers' responses to policy changes vary from one household to another depending on location, resource endowment, land use, market access, land tenure, age, sex, economic situation, family composition, etc. This may be particularly true, for example, in the case of policy instruments that bring about changes in household production and consumption. The extent and direction of these effects will depend on the behaviour of each operator, which in turn depends on his or her characteristics, preferences, location, etc. A micro-analysis is therefore needed to take account of the disparity between holdings and to identify the winners and losers of existing or alternative policies.

FSSIM-Dev has a generic and modular configuration so that it can be easily adapted to and reused for new policy issues and/or different biophysical and socioeconomic conditions. Due to its generic and modular nature, this model can be applied to individual (i.e. real) or representative (i.e. typical or average) households. It can also be used to analyse the decisions of farmers who are entirely market-oriented as well as those of (semi-)subsistence farmers or farmers operating in imperfect markets.

3.1.2 Structure and mathematical formulation of the FSSIM-Dev model

FSSIM-Dev is a non-linear static optimisation model that is based on both the household's general utility framework and the technical constraints of agricultural production, in a non-separable regime. Based on positive mathematical programming (Howitt, 1995), FSSIM-Dev maximises an objective function subject to a series of resource endowment, human consumption and agricultural policy constraints. It assumes that the farm household maximises its expected income, defined as the income earned from all economic activities of a family living in the same household, namely: farm income, income from marketed production factors (non-farm wages, rent of land and/or equipment, etc.) and off-farm income (i.e. from outside the holding). Farm income is defined as the sum of revenues that a farm household obtains by selling or consuming its own agricultural products. Off-farm income are exogenous to the model (treated as constant variable or given). They may come from various sources such as non-farm wages, small businesses, self-employment, pensions, transfers and gifts.

Farm income is defined as the sum of the expected gross margins, less a non-linear (quadratic) behavioural function specific to each activity of the farm household. Gross margin is the total revenue, including sales and self-consumption, plus subsidies and less operating costs. Operating costs include seed, fertiliser and plant health product (pesticide) costs and other specific costs. The quadratic function is a behavioural function introduced to calibrate the model to an observed situation, as it is generally the case with positive mathematical programming models. This function aims to precisely replicate the production and consumption decisions of farm households by capturing the effects of factors that are not explicitly included in the model, such as capital costs, risk aversion, price anticipation, model specification errors, etc. (Heckelei, 2002; Henry de Frahan et al., 2007; Paris et Howitt, 1998).

The model's general mathematical formulation is as follows:

(E1)
$$\begin{aligned} Max\ Z_h = & \sum_i (s_{h,i} + cs_{h,i}) p_{h,i} + \sum_i sb_{h,i} x_{h,i} - \sum_{i,k} a_{h,i,k} x_{h,i} - \sum_i (\mathrm{d}_{h,i} + 0.5 Q_{h,i,i'} x_{h,i'}) x_{h,i} \\ & + \sum_{tf} (s_{h,tf} - b_{h,tf}) p_{h,tf} \ + ExInc_h \end{aligned}$$

s.t.

(E2)
$$\sum_m A_{i,m} x_i \le B_m + b_m - s_m \qquad [\rho_m]$$

(E3) $$c_{h,j}p_{h,j} = \beta_{h,j}(Z_h - \sum_{j'}\gamma_{h,j'}p_{h,j'}) + \gamma_{h,j}p_{h,j}$$

(E4a) $$p_j^m t_{h,j}^s \le p_{h,j} \le p_j^m t_{h,j}^b$$

(E4b) $$p_{tf}^m t_{h,tf}^s \le p_{h,tf} \le p_{tf}^m t_{h,tf}^b$$

(E5) $$s_{h,j}b_{h,j} = 0$$

(E6a) $$s_{h,j}(p_{h,j} - p_j^m t_{h,j}^s) = 0$$

(E6b) $$b_{h,j}(p_{h,j} - p_j^m t_{h,j}^b) = 0$$

(E7) $$q_{h,j} + b_{h,j} = s_{h,j} + c_{h,j}$$

(E8) $$c_{h,j} = cs_{h,\mathrm{j}} + b_{h,j}$$

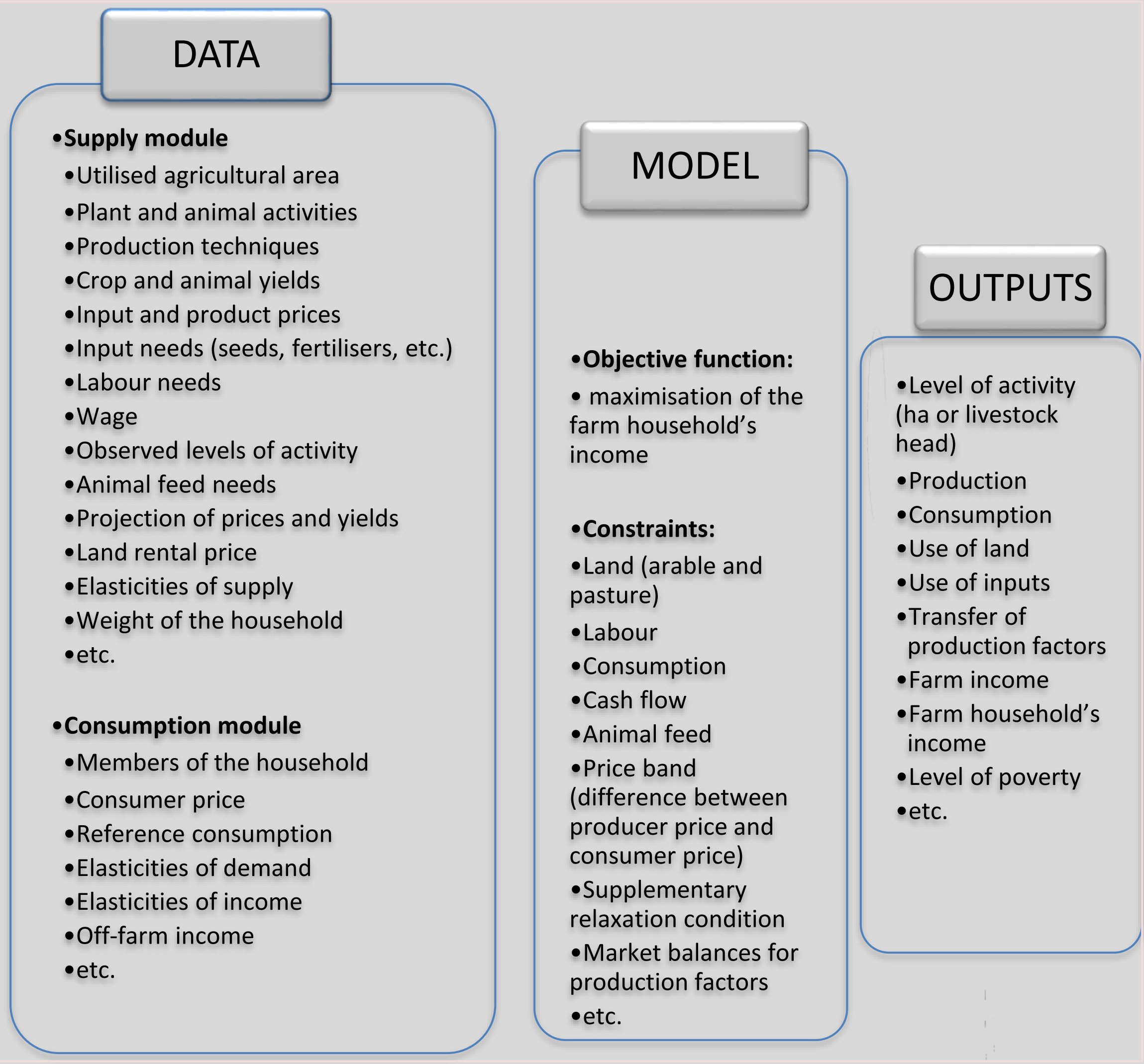
(E9a) $$\sum_h w_h s_{h,j} + M_j = \sum_h w_h b_{h,j} + E_j$$

(E9b) $$\sum_h w_h s_{h,tf} + M_{tf} = \sum_h w_h b_{h,tf} + E_{tf}$$

where **Z** is the income of the farm household **h**, **p** is the vector (n×1) of the prices of goods **j** and potentially exchangeable production factors **tf** (land, work) of the farm household **h**, **s** is the vector (n×1) of the quantities of goods sold or production factors transferred, **cs** is the vector (n×1) of the quantities of self-consumed goods, **x** is the vector (n×1) of the optimal agricultural activities **i**, **sb** is the vector (n×1) of the production subsidies (where applicable), **a** is the matrix (n×k) of the variable costs of inputs **k**, **q** is the vector (n×1) of the quantities of goods produced on the farm holding, **b** is the vector (n×1) of the quantities of goods purchased or production factors rented, and **c** is the vector (n×1) of the quantities of goods consumed. γ is the vector (n×1) of the uncompressible consumption of the household, $\boldsymbol{\beta}$ is the vector (n×1) of the household's preferences (budget share) for product **j**, the sum of which must be equal to one, $\mathbf{p^m}$ is the vector (n×1) of the market prices of goods **j**, and $\mathbf{t^b}$ and $\mathbf{t^s}$ are respectively the vectors (n×1) of the transaction costs borne by the household in the purchase or sale of goods **j** or factors **tf**. **d** is the vector (n×1) of the linear part of the behavioural function and **Q** is the symmetrical and positive (semi-defined) matrix (n×n) of the behavioural function. **A** is the matrix (n×m) of the technical coefficients, **B** is the vector (m×1) of the initial resource endowments (land, work) and ρ is the vector (m×1) of their respective marginal values. **ExInc** is a parameter that represents the off-farm income, **w** is the household's weighting factor (i.e. the weight of the household in the region), and **M** and **R** are respectively the quantities of production factors and products imported and exported from/to other regions. **Q, d** and ρ are estimated using a variant of the positive mathematical programming (Louhichi et al., 2017). $\boldsymbol{\beta}$ and γ are estimated using a Bayesian approach known as Highest Posterior Density (Heckelei et al., 2008).

A number of constraints are taken into account in FSSIM-Dev in order to model (i) the holding's resource endowment (E2), (ii) the linear expenditure system (LES) function representing the household's consumption (E3), (iii) the discontinuity in the market participation decision due to the existence of transaction costs (E4a and E4b) (i.e. these transaction costs increase the prices actually paid by buyers and reduce the prices actually received by sellers), (iv) the supplementary relaxation conditions to ensure, firstly, that, for each product, a farm household can be buyer or seller but not both at the same time (E5) and, secondly, that a farm household can live self-sufficiently and use its own price (E6a and E6b), and finally (v) the two market balance conditions: the first (E7 and E8) guarantees the balance of products at the level of each household, i.e. for each product, the sum of the production and purchases must equal to the sale plus consumption; and the second (E9a and E9b) guarantees the balance of the supply and demand of products and exchangeable factors at the aggregated level (region or village).

Box 2: Overview of the FSSIM-Dev model structure



For this study, the FSSIM-Dev consumption module was calibrated using the consumption expenditure dataset available from the LSMS-ISA (see below). The supply module was calibrated using the production of the 2010/2011 crop campaign (both dry and rainy seasons), corresponding to the period covered by the LSMS-ISA in Niger. The calibration was carried out at individual level by using the Bayesian HPD (Highest Posterior Density) method and prior information on supply elasticities (Louhichi et al., 2015). The model's parameters were calibrated so that the model accurately reproduces the observed distribution of land between irrigated and non-irrigated crops. The parameters of the behavioural function were estimated only for observed activities in each farm household, which means that the problem of self-selection was not explicitly tackled by this estimate. To solve this problem, we adopted the following modelling assumptions in the simulation phase: in each region, the gross margin of non-observed activities for a given farm holding is equal to the average gross margin for holdings of the same farm type, the parameter of the quadratic function of the activity is equal to the parameter of the average quadratic function of the activity for holdings of the same type, and the quadratic function of the linear term is derived from the difference between the gross margin and the *dual values* of the constraints. In other words, the adoption of new activities (non-observed) by a farm holding remains possible by using the parameters of observed activities on other holdings of the same farm type and in the same region.

3.2 Data used

The simulation exercises whose results are displayed in this document are performed based on data from a household survey, namely the LSMS-ISA (Living Standards Measurement Study - Integrated Surveys on Agriculture) survey conducted in Niger in 2011. This very comprehensive survey was carried on by the National Statistics Institute (*Institut National de la Statistique* – INS) of Niger with the technical and financial support of the World Bank. The data were collected in two stages so that both activities from the dry season (first wave, from December 2010 to May 2011) and rainy season (second wave, from June 2011 to November 2011) were covered. The complete survey sample comprised approximately 4,070 households, all involved in agricultural activities (including livestock). In this LSMS-ISA survey, households are defined as a single consumption unit. The survey sample was obtained using a two-stage random sampling technique and was stratified into four agro-ecological zones, namely urban, agricultural, agro-pastoral and pastoral zones. The final sample was representative of urban and rural zones at the national level. Three different questionnaires were used, corresponding to different data collection levels: community level (village), household level and a level specific to agricultural activities.

The household questionnaire for the Niger 2011 LSMS-ISA survey comprised a number of different modules and allowed information to be gathered on numerous aspects of the household livelihoods and farming activities. The modules used in this study covered three main themes: (1) household activities, consumption and means of subsistence, (2) agricultural activities, and (3) livestock activities.

1. The household data were collected in such a way that all food and non-food expenditures of households were taken into account. The methodology used to collect food consumption data was the 7-days diet records (collected twice, once in each wave of the survey). All non-agricultural activities and any source of off-farm income were recorded for all members of the household.
2. The data on agricultural activities consisted of a full description of all plots on the farm, land tenure, type of soil and available infrastructures (anti-erosion, irrigation, etc.). Production cost data (labour and inputs) were collected at plot level. The quantity of family and paid labour employed for each crop and each plot was also enquired. Agricultural production was recorded for each plot and each crop on the plot. The area of plots was measured using GPS in most cases.
3. The data on livestock activities consisted of a full description of all types of animal herd belonging to the farmers, the various products and volumes sold (milk, leather, meat, etc.) and the production costs.

All the 2011 LSMS-ISA data were carefully cleaned and processed, before being used in the FSSIM-Dev model to ensure that this work was carried out properly. Variables such as crop yield, quantity of inputs used and prices were checked in order to eliminate outliers (by using the Tukey method based on the interquartile range in most cases) and missing values. However, the main limit of this dataset was that, during the 2011 marketing year, Niger experienced a severe drought that considerably affected the rain-fed crop season. Consequently, the yields calculated using the survey data were very low, particularly for grains such as millet and sorghum. As they did not correspond to the assumptions made by farmers when making crop allocation decisions, we replaced those data with the expected yields, calculated using, in particular, the estimate of losses declared by farmers.

Lastly, as this work mainly concerns the issue of irrigation, we excluded from the final sample any holdings focusing exclusively on livestock. The final size of our sample was therefore 2,322 households. The main characteristics of the sample used for this work are set out in the following table.

Table 2. Characteristics of the holdings in the sample used

Region	Agadez	Diffa	Dosso	Maradi	Tahoua	Tillabéri	Zinder	Niamey	Niger
Number of households in the sample	108	227	389	389	378	374	384	73	2,322
Average area cultivated in the rainy season in ha (standard deviation)	0.97 (1.5)	4.48 (3.66)	4.76 (3.59)	5.0 (4.99)	4.03 (3.87)	7.76 (6.54)	5.39 (5.23)	1.94 (3.44)	4.99 (4.94)
Number of irrigating holdings	89	53	37	7	54	41	20	46	347
Area cultivated in the dry season in ha	0.25	1.0	0.25	0.09	0.44	0.62	0.91	0.49	0.54
Crop allocation in the rainy season – main crops (% 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
Rice	16.4							6.0	0.6
Cowpea	4.4	10.1	28.3	33.1	26.4	21.6	30.7	22.9	25.6
Groundnut		4.3	6.5		4.7				3.6
Onion	34.9								0.6
Crop allocation in the dry season – main crops (% by region)									
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
Chilli pepper				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
African eggplant							52.2		8.1
Onion	45.2			7.9	77.4	7.5			16.5
Squash						7.9	5.2		2.4

Source: authors' calculations based on 2011 LSMS-ISA data

3.3 Scenario for the ex-ante analysis of the impacts of small-scale irrigation on Nigerien households

As indicated above, the FSSIM-Dev model was calibrated using LSMS-ISA data collected from 2,322 farm households in Niger. By calibration we mean estimating the parameters of the behavioural function which makes it possible to accurately reproduced the observed crop allocation decisions of each farmer (i.e. as it was declared by farmers in the household survey). This situation is called the *baseline*. It is used as a reference or comparison point for analysing the effects of the simulated policy, which, in the present case, is the extension of irrigated land.

In order to simulate a policy such as a small-irrigation program, this measure should first be analysed and transcribed into mathematical language so that it can then be easily implemented in the farm household model. This generally requires making a number of assumptions about the way some model's parameters would change. Typical parameters to change are prices of inputs or output, utilised agricultural area or use of a particular technique by farmers. Any change to a parameter of the baseline is known as a 'shock', to which the model reacts by simulating the behaviour adopted by agricultural households faced with this change. A scenario therefore corresponds to a shock or a series of shocks and is intended to reproduce, as effectively as possible, the new situation that would result from the development programme or policy that is being simulated. The model's usefulness lies in the fact that based on the observed behaviours of agricultural households, it identifies the likely effects of simulated policies.

In this study, we have focused on the support mechanism corresponding to what the SPIN action documents call a 'normal' application, which represents most of the subsidies granted. Therefore, the objective of the study is to assess to what extent this support mechanism contributes to the objective of improving food security and reducing poverty in Niger.

Two scenarios were developed. In both cases, we simulated increased access to irrigated land for farm households and assessed the potential impacts in terms of (i) crop allocation, (ii) distribution of land between irrigated and non-irrigated crops, (iii) agricultural production and (iv) agricultural income.

The **first scenario** corresponds to the situation that would exist if the target of equipping 4,700 hectares of land with small-scale irrigation (i.e. 4,200 ha of newly irrigated land and 500 ha of restored irrigated land) per year over 10 years were reached. By 2015, 47,000 additional hectares would therefore be available to Nigerien farm households. Consequently, in order to model this scenario, an equivalent ceiling was set for the increase in the total area equipped with small-scale irrigation, and we assumed that this area would be allocated to the most successful holdings on these new irrigated plots. In addition, in this scenario, the areas equipped were distributed by region in proportion to their potential irrigable land. The assumptions made about funding corresponded to the arrangements specified by SPIN for a 'normal application,' i.e. 10% of the investment paid by the farmer, 40% subsidised and 50% in the form of a loan. Furthermore, a ceiling of 0.5 hectares of irrigated land was set for all new irrigators in order to distribute the investment as effectively as possible among a larger number of holdings. Lastly, in this scenario, only households without any irrigated land (new irrigators) were eligible to benefit from the support of the program.

The **second scenario** corresponds to the situation that would exist if the area equipped with small-scale irrigation were increased to a total of 270,000 hectares, i.e. an increase of over 160,000 hectares. In this second scenario, the small-scale irrigation area ceiling was therefore set to 270,000 hectares in total. Furthermore, in this scenario, this area was not forced to be distributed among the various regions. Once again, the funding rules corresponded to a 'normal application', yet all farmers were eligible, including those who already had irrigated land. The subsidised area per holding was capped at 1 hectare. This second scenario therefore corresponded to a kind of 'extended SPIN'.

In both scenarios, the initial investment cost was set to the level of the average cost to equip one hectare of small-scale irrigation with fencing and without fencing (see Table 3). In addition, all other operating costs, particularly those related with the irrigation of new plots – electricity, fuel or pump maintenance costs – were assumed to be covered by the farm households. The model therefore gives the choice to farmers to adopt or not small irrigation within the terms offered by the SPIN, depending on their specific conditions, their economic performance (gross margin of irrigated crops in the region), their resource endowments, and their cost structure. It should be noted that, in our simulations, the adoption of irrigation is based only on economic considerations in the broad sense (there is no 'technical unfeasibility' *stricto senso,* or in other terms, it is assumed that water would be available anywhere. However, it places where no irrigation is currently undertaken, it would be associated with high and prohibitive implicit costs).

Table 3. Average cost of equipping a plot with small-scale irrigation

Region	Approximate average cost of the investment for one hectare of small-scale irrigation involving small boreholes (CFA francs/ha)		
	(without fencing)	(with fencing)	Average
Agadez[1]	1,475,000	4,250,000	2,862,500
Diffa	1,700,000	4,800,000	3,250,000
Dosso	1,600,000	4,200,000	2,900,000
Maradi	1,300,000	4,100,000	2,700,000
Tahoua	1,550,000	4,300,000	2,925,000
Tillabéri	1,650,000	4,350,000	3,000,000
Zinder	1,350,000	4,200,000	2,775,000
Niamey	1,200,000	3,800,000	2,500,000

Source: SPIN Permanent Secretariat (2019).

Note (1): For Agadez, in the absence of data, we have used the average of the other regions.

Table 4. Assumptions of the scenarios constructed to simulate the impacts of SPIN

	Maximum area newly equipped per holding	Funding arrangement (% contribution – subsidy – loan)	Open to current irrigators	Distribution of newly equipped areas according to the potential irrigable land of each region
Scenario 1 – SPIN	0.5 ha	10-40-50	No	Yes
Scenario 2 – Extended SPIN	1 ha	10-40-50	Yes	No

In both scenarios, the effects were measured at the level of farm holdings, which were representative of all Nigerien holdings. Results were then aggregated by type of holding or by region.

4 Results: Effects of the small-scale irrigation program on farm households

The results presented here describe the effects of the SPIN on farming households forming part of the baseline used for the FSSIM-Dev model in Niger. However, as the 2011 LSMS-ISA from which the data were taken is a representative survey, it is also possible to extrapolate those results at regional and national levels using the statistical weight of each household. Furthermore, we would note that, in order to make the results easily interpretable, a typology of farm households was constructed, based on their economic size, specialisation and degree of integration to the markets.

4.1 Effects on agricultural production

4.1.1 Effects on irrigated agricultural area

Unsurprisingly, the effects on agricultural area indicate a significant increase in irrigated area, which clearly corresponds to the main aim of SPIN. This confirms the attractiveness of irrigation to farm households: if they are offered the opportunity to increase their irrigated area under the conditions of the different scenarios, they are willing to make the necessary investments and allocate their assets (land and labour) to irrigated crops. We would note that the results presented in Table 5 correspond to the sum of the areas irrigated during both the rainy and the dry seasons. Some plots are therefore counted twice. It is thus more prudent to analyse the areas irrigated by growing cycle.

Scenario 1 would lead to an increase in the total area irrigated in the dry season in Niger of approximately 44%, compared with the baseline. The total irrigated area would therefore be nearly 154,000 hectares, i.e. an increase of 47,200 hectares. These results, which are conform to the assumptions of this scenario, simply show that this SPIN target is realistic. Furthermore, in this scenario, the area irrigated during the rainy season also increases, although less significantly, i.e. by 16%, which would result in a total of 48,580 hectares, i.e. 6,800 hectares more than in the baseline. The lesson here is that the policy aiming at increasing the area of land equipped with small-scale irrigation for the dry season would also allow certain farmers to benefit from this during the rainy season. This is particularly the case in the most northerly regions of the country, where irrigation can mitigate the irregularity of rain in the winter.

Under the assumptions of Scenario 2, the increase in irrigated area is even greater. In the dry season, the irrigated area totals 273,000 hectares (+156% compared to the baseline), i.e. approximately 120,000 hectares more than in the previous scenario. This scenario is therefore useful for identifying the potential impacts on Nigerien farm households and the country's agricultural production of a very significant increase in irrigated area.

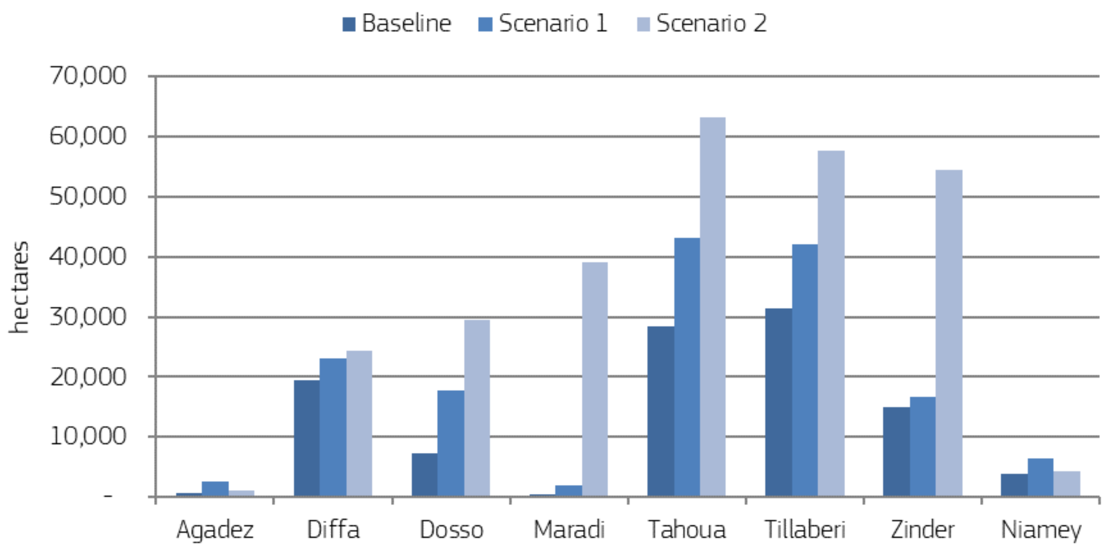
Table 5. Area cultivated and irrigated in the SPIN simulation scenarios

	Area cultivated in the rainy season (ha)		Area cultivated in the dry season (ha)		Total for both seasons (ha)	
	Total	Irrigated	Total	Irrigated	Total	Irrigated
Baseline	10,529,461	41,772	106,609	106,609	10,636,070	148,380
Scenario 1	10,522,057	48,580	153,872	153,872	10,675,929	202,451
Scenario 2	10,527,737	96,443	273,459	273,459	10,801,196	369,901

The following figures show in which regions the increase in irrigated area would occur as a result of the SPIN. Although nearly all the regions are concerned by the increase, the Agadez and Niamey regions differ since, in these, the irrigated area increases much less than in the rest of the country, in absolute terms (**Figure 1**). This may be explained by the limited availability of water for irrigation during the dry season, which results in relatively high investment and operating costs for new sources of water (i.e. the implicit costs in the model). Moreover, in the Niamey region area, many farmers are already irrigators and therefore, for them, extending their irrigated land further may come up against labour constraints, prohibitive marginal production costs or even new areas rarely being available for irrigation. Due to the proximity of the capital city and the corresponding demand for market garden products, areas suitable for irrigation are often already utilised in this way, whilst urban growth is tending to limit the agricultural area available for new development.

The Maradi region is another extreme case. In the moderate increase scenario (Scenario 1), this region gains very little new irrigated area in the dry season (+1,500 ha), because its irrigable potential is low. However, in Scenario 2, which does not take account for the irrigable potential of each region, this region gains over 38,000 hectares. This increase is the same as what is observed in the Zinder region, but represents a considerable increase for a region where irrigation is not particularly developed in the baseline. Therefore, it is likely that this second scenario overestimates the potential for small-irrigation in Maradi.

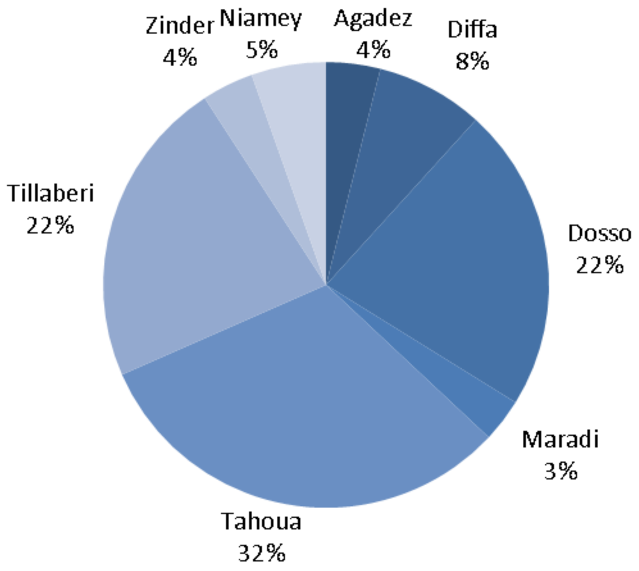
Figure 1. Area irrigated in the dry season by region in the SPIN simulation scenarios



In the other regions (Dosso, Tahoua and Tillabéri), the increase in irrigated area in Scenario 1 is in the range of 10,000 hectares to 15,000 hectares in the dry season, which seems reasonable for those regions where irrigation is already more well-established. Lastly, in this same scenario, the Diffa region would register an increase in irrigated area of 3,700 hectares (+19%) in the dry season compared with the baseline.

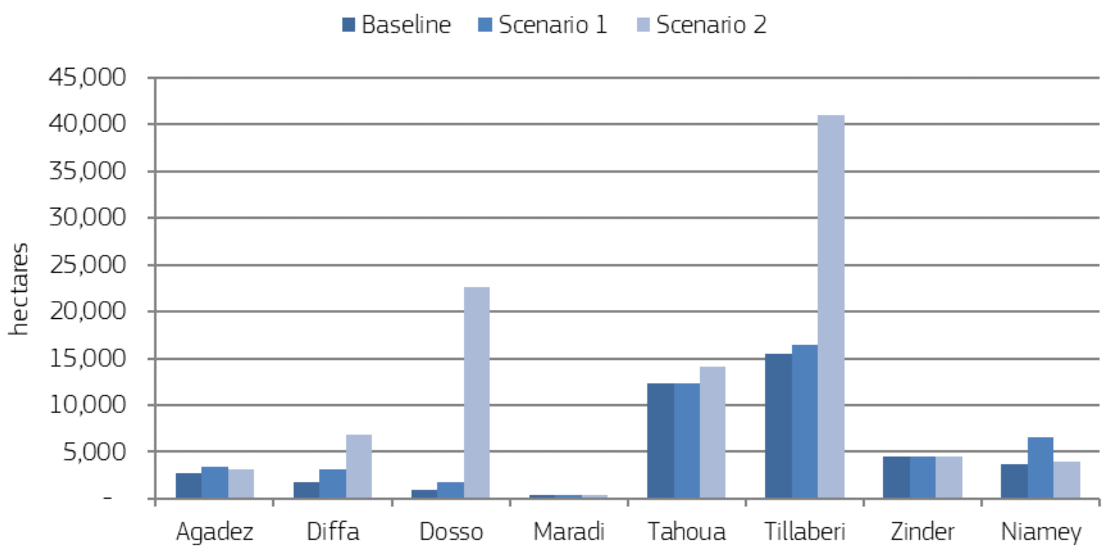
Figure 2 shows how the newly irrigated areas would be distributed by region in Scenario 1. The Tahoua region would register the largest increase in newly irrigated areas (gaining 32% of the 47,000 additional hectares in Niger), followed by Dosso and Tillabéri. The Agadez, Maradi, Niamey and Zinder regions would together account for only 15% of the newly irrigated areas.

Figure 2. Distribution of the new areas equipped with small-scale irrigation by region (Scenario 1)



In the rainy season (Figure 3), the increase in area equipped with small-scale irrigation by region would be lower, although still significant in relative terms in the Dosso (+86%), Niamey (+81%) and Diffa (+75%) regions for Scenario 1.

Figure 3. Area irrigated in the rainy season by region in the SPIN simulation scenarios



As indicated above, a typology of farm households comprised in the sample was constructed in order to allow the results to be analysed in more detail. This typology consisted of 5 classes of holding, categorised according to their specialisation (a holding was regarded as specialised if more than two-thirds of its gross income came from the same category of crop, such as traditional crops like millet or sorghum, or market garden crops for example), market integration (proportion of the production with a commercial value) and economic size (total value of the agricultural production). This typology was therefore as follows:

- Type 1 – Small holding with traditional crops: holding with an economic size below the median, specialising in traditional products such as millet, sorghum, cowpea, tigernut or fonio.
- Type 2 – Large holding with traditional crops: same specialisation as the previous category, but larger economic size. In addition, these holdings are more market-oriented.

- Type 3 – Holding with non-traditional and cash crops: these are holdings that are highly integrated in markets and that specialise in crops such as rice, corn, groundnut, sesame, cassava, wheat, sweet potato, etc.
- Type 4 – Market garden holding: holdings integrated in markets and focusing on market gardening (lettuce, sweet pepper, tomato, onion, chilli pepper, okra, carrot, cabbage, bean, lettuce, squash, etc.).
- Type 5 – Diversified holding: holding where the gross income comes from different categories of crop.

Table 6. Average irrigated area by type of holding in the dry season (hectares per holding)

	Baseline	Scenario 1	Scenario 2
Type 1 – Small holding with traditional crops	0.00	0.03	0.09
Type 2 – Large holding with traditional crops	0.00	0.00	0.09
Type 3 – Holding with non-traditional and cash crops	0.13	0.17	0.19
Type 4 – Market garden holding	0.69	0.69	0.71
Type 5 – Diversified holding	0.10	0.15	0.17

Table 6 shows, for each type of holding, the average area equipped with small-scale irrigation that is available to the holding in the dry season. All holdings were taken into account in the calculation of this average, including those without any irrigated land. In the baseline, traditional holdings, whether small or large (types 1 and 2), do not have any irrigated area, whilst non-traditional crop (type 3) and diversified (type 5) holdings cultivate an average of 1,000 square metres of irrigated area in the dry season. However, market garden holdings (type 4) have an average area for irrigated off-season crops of nearly 0.7 hectares.

The modelling exercise allows the types of holding that would most benefit from a policy such as SPIN to be identified. The figures in **Table 6** show that, in Scenario 1, the average irrigated area per holding increases in the dry season for most types of holding. As a result, small traditional holdings (type 1) that generally produce only the triptych of millet-sorghum-cowpea would gain, due to the support provided by SPIN, a modest irrigated area (300 m2 in Scenario 1 and 900 m2 in Scenario 2). Non-traditional holdings or those that are relatively diversified (types 3 and 5) would also benefit from SPIN: an increase of 500 m2 of irrigated land for type 5 holdings and 400 m2 for type 3 holdings. These increases may seem modest, but it should be remembered that these figures are averages for all Nigerien holdings, including those not benefiting from the SPIN. Furthermore, the income earned from irrigated crops, even in small areas, is far from negligible, as we will see below. Lastly, market garden holdings, which mostly already have irrigation, would not see their irrigated area increase in Scenario 1 and would see only a small increase in Scenario 2. In this scenario involving an even more extensive development of small-scale irrigation, types 1 and 2 traditional holdings would clearly benefit more, with their area increasing in both cases to 900 meters square.

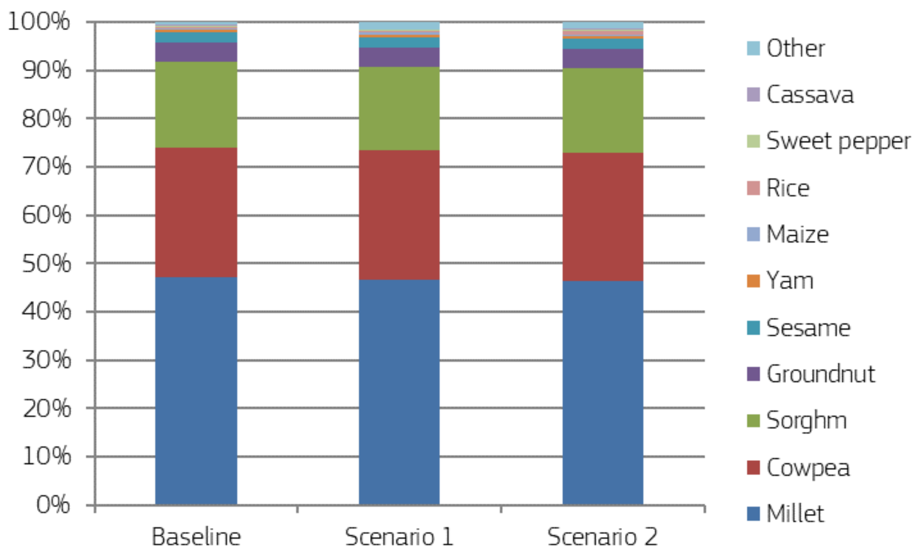
It is clear from these results that, due to SPIN, those holdings that currently operate with the least irrigation infrastructure would be the ones to most increase their irrigated area in the dry season, in relative terms. Particularly for small traditional holdings, the dry season is generally a difficult period with a lack of income and possible hunger gap because these farmers cannot produce anything else. It is therefore highly likely that the benefits in terms of income and food security will be significant for these holdings.

4.1.2 Effects on crop allocation

Figure 4 shows the impact of the small-scale irrigation programme on the general crop mix in Niger during the rainy season. It is clear that the developments enabled by SPIN (Scenario 1) or an even more ambitious programme (Scenario 2) would not have significant effects on how farmers allocate their land in the rainy season. This is a fairly logical result given that irrigation is mainly used in the dry season, although, in some regions such as Agadez or in the north of Tillabéri or Tahoua, producers also use irrigation in the rainy season to complement or mitigate rain variability or scarcity.

In the absence of any significant impact from the irrigation development programme, the traditional crops of millet, cowpea and sorghum would therefore continue to predominate in the general crop mix in Niger during the rainy season, with respectively 46%, 27% and 17% of the area planted in this season in Scenario 1. This represents 4.9 million hectares for millet, 2.8 million hectares for cowpea and 1.8 million hectares for sorghum.

Figure 4. Effect of SPIN on crop rotation in Niger in the rainy season



The increase in irrigated area does, however, have a very significant impact on crop mix in the dry season (see **Figure 5**). In the baseline, three crops alone account for nearly three-quarters of the area cultivated in the dry season in Niger: onions (29% of the area), rice (25%) and sweet peppers (19%). Onions, which are mainly grown in the Tahoua region and, to a lesser extent, in Maradi, are traditionally the most important off-season crop in Niger and represent a significant source of export income. This plant does not like high humidity and therefore lends itself very well to dry-season irrigated cropping systems where it is easier to control the supply of water. Scenario 1 shows that this crop would not lose any of its importance, in fact far from it, if the SPIN targets in terms of irrigated area were met. Accordingly, onions would remain the main dry-season crop with over 47,500 hectares sown, representing an increase of over 55% (mainly in the Tahoua region). Rice and sweet peppers would still come next after onions, but would see more moderate increases (+6% of irrigated area for rice and +18% for sweet peppers). However, behind these top three, the order would change due to the emergence of squash as the fourth most important crop in terms of area cultivated in the dry season, with nearly 7,800 hectares (mostly in the Tillabéri region), which would represent more than a tripling of the area of this crop. We further note that, in Scenario 1, the chilli pepper crop would also significantly increase (+133% of irrigated area devoted to this crop in the dry season, i.e. over 7,750 hectares), as also sweet potato (+139%, i.e. nearly 5,700 hectares, mainly in Tillabéri). Lastly, we note the very significant increases in the production of lettuce (+272% of irrigated area) and cabbage (+252% of irrigated area in the dry season). In sum, one of the lessons of this Scenario 1 is that not only would the implementation of the SPIN lead to a very significant increase in market garden production, but it would also help to very much diversify the mix of crop cultivated.

Lastly, the scenario involving an even more extensive development of small-scale irrigation (Scenario 2) shows that the trends described above would continue if the irrigated area were increased even further. Onions would remain the main crop and would exceed the threshold of 100,000 hectares, but behind, the order would change due to the spectacular increase in the cultivation of squash, which would take the second place with nearly 70,000 hectares cultivated. Lettuce, with over 15,000 hectares, would also see its production increase by more than ten-fold.

Figure 5. Effect of SPIN on crop mix in Niger in the dry season

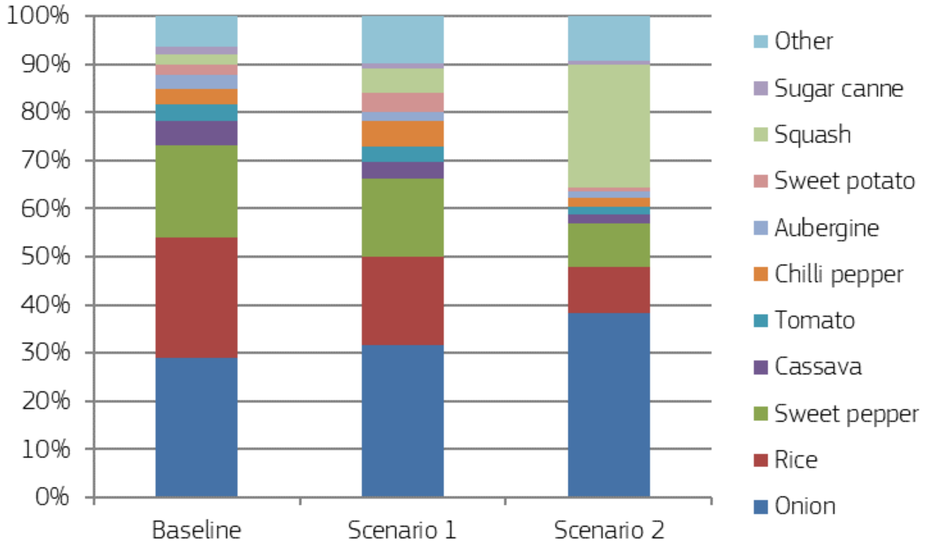


Figure 6. Crop mix in the dry season as a result the SPIN simulation for each region (Scenario 1)

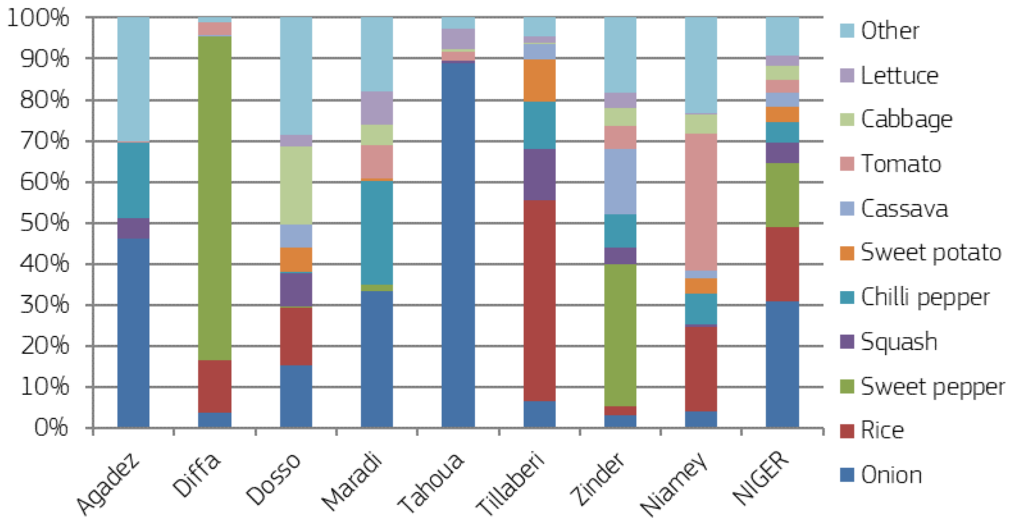


Figure 6 and **Table 7** show the crop mix in the dry season that would result in each region from implementing the SPIN (Scenario 1). The main lesson from these figures is that each region would adopt a very different range of crops, reflecting the local agro-ecological conditions and the fact that some regions are more suited to certain crops than others. We therefore note the very high specialisation of the Tahoua region in the cultivation of onions, with 38,000 hectares in the dry season (nearly 90% of the crop area), and, to a lesser extent, that of the Agadez region where onions would occupy 46% of the area in the dry season. The Diffa region would continue to specialise in the cultivation of sweet peppers (over 18,000 hectares in the dry season in Scenario 1). Conversely, the Dosso, Zinder and Niamey regions would see a relative diversification of the off-season cropping systems, with significant production of sweet pepper, chilli pepper, squash, tomato (in Niamey) and even cabbage. Last is Tillabéri, where nearly half of the area irrigated in the dry season would be dedicated to rice, but where the other half would see a fairly wide range of crops, such as squash, chilli pepper, sweet potato and even onions.

Table 7. Cultivated area of the main crops in each region of Niger (Baseline and Scenario 1)

Baseline	Agadez	Diffa	Dosso	Maradi	Tahoua	Tillabéri	Zinder	Niamey	NIGER
Onion	342	828	365	18	25,771	2,801	509	59	**30,695**
Rice	-	2,975	2,171	-	-	19,466	378	1,244	**26,234**
Sweet pepper	-	14,549	44	18	-	-	5,785	41	**20,438**
Squash	15	3	69	-	39	1,911	72	12	**2,120**
Chilli pepper	26	7	53	73	-	2,352	552	260	**3,323**
Sweet potato	-	-	898	18	-	1,450	-	12	**2,379**
Cassava	-	13	977	-	-	1,508	2,685	124	**5,306**
Tomato	25	717	21	107	827	19	866	1,087	**3,670**
Cabbage	-	50	84	56	210	128	693	167	**1,389**
Lettuce	-	8	86	56	479	72	392	25	**1,119**
Other	301	226	2,516	129	1,063	1,710	3,070	921	**9,937**
TOTAL	**710**	**19,378**	**7,283**	**474**	**28,391**	**31,418**	**15,002**	**3,954**	**106,609**
Scenario 1	**Agadez**	**Diffa**	**Dosso**	**Maradi**	**Tahoua**	**Tillabéri**	**Zinder**	**Niamey**	**NIGER**
Onion	1,185	854	2,710	654	38,508	2,802	530	270	**47,513**
Rice	-	2,993	2,493	-	-	20,494	378	1,342	**27,700**
Sweet pepper	-	18,197	44	34	-	-	5,785	-	**24,061**
Squash	123	3	1,454	-	252	5,226	695	43	**7,795**
Chilli pepper	475	7	53	490	-	4,892	1,350	482	**7,748**
Sweet potato	-	-	1,048	18	-	4,387	-	236	**5,689**
Cassava	-	13	985	-	-	1,511	2,685	121	**5,314**
Tomato	4	717	21	158	911	19	948	2,179	**4,957**
Cabbage	-	50	3,350	98	230	154	693	308	**4,883**
Lettuce	-	8	524	155	2,248	558	643	28	**4,164**
Other	773	226	5,052	354	1,095	1,972	3,070	1,507	**14,049**
TOTAL	**2,561**	**23,070**	**17,734**	**1,960**	**43,243**	**42,014**	**16,776**	**6,515**	**153,872**

In sum, there is no doubt that implementing SPIN would have significant consequences on the cropping and production systems. The most direct effect would be an increase in the total area and in the area per holding used for irrigated and off-season crops. In the next section, we will explore the effects of these changes on the economic performance of Nigerien holdings.

4.2 Economic impacts of implementing the SPIN

In this section, we will focus on the economic effects of the SPIN, particularly in terms of economic benefits – additional farm income – for Nigerien farm households. However, we will first try to estimate the cost of the programme for the State in order to compare the costs and benefits.

4.2.1 Estimate of the cost of implementing the SPIN

Using the estimated area of new plots irrigated in the dry season for each of the two SPIN scenarios presented above, we can estimate the cost of the operation for the State or any donors. The cost of equipping one hectare with small-scale irrigation will vary according to the type of irrigation used, location, local operators, etc. It is also highly likely that, in an operation with the scope of the SPIN, economies of scale will be achieved and the marginal cost of the investment could decrease. Based in particular on information available locally and on previous small-scale irrigation development projects (*Ministère de l'Agriculture*, 2015b), we can assume a reasonable range of 1 million CFA francs to 4 million CFA francs for the cost of one hectare equipped in Niger.

Multiplied by the area equipped, the State's[1] share of this investment will therefore be between 18 billion CFA francs and 75 billion CFA francs (i.e. between 29 million euro and 115 million euro). Scenario 2 will be more costly for the State as it will require a minimum investment of 66 billion CFA francs (100 million euro).

Table 8. Estimate of the cost of implementing SPIN for the State budget

	New area irrigated in the dry season	Cost of the investment per ha (CFA francs per ha equipped)		Total cost for the State (million CFA francs)	
		Min.	Max.	Min.	Max.
Scenario 1	47,260	1,000,000	4,000,000	18,905	75,620
Scenario 2	166,850	1,000,000	4,000,000	66,740	266,960

There is no doubt that the SPIN, whether the standard or extended version, will require a considerable investment on the part of Niger public budget. We should now analyse the potential benefits of this investment.

4.2.2 Effects of the SPIN on farm income

The effects of the SPIN (Scenario 1) and extended SPIN (Scenario 2) on the farm income of Nigerien holdings are reported in **Table 9**. Unsurprisingly, these effects are unremarkable for farm income in the rainy season in most regions, given the limited changes made by the SPIN to production systems in that season. The only exception are the Agadez and Niamey regions, where access to irrigation would result in a significant increase in income, even in the rainy season. In the other regions, however, the effects would be felt much more markedly in the dry season.

Accordingly, in the Agadez and Niamey regions, where there would be a relatively significant increase in the area irrigated in the dry season, particularly as the baseline figures are relatively low, holdings would see a significant increase in their income during this season if the SPIN were fully implemented (Scenario 1): +316% in Agadez and +536% in Niamey. In absolute terms, these increases in income would correspond to an expansion in gross farm income of around 300,000 CFA francs in Agadez and 377,000 CFA francs in Niamey. The relative increase in income would also be substantial in Dosso, although the starting point (baseline) is relatively low.

The average increase in farm income would also be significant in Tillabéri (+110%), Zinder (+40%) and Tahoua (+38%), in relative terms. For Niger as a whole, the average increase in farm income in the dry season would be 41,000 CFA francs for the standard SPIN modelling scenario, which represents an increase of 78%. In the extended SPIN scenario, this increase would be 422%. However, while these increases are significant in

(1) As a reminder, the State subsidises 40% of the cost of SPIN, which is the figure used for Scenarios 1 and 2.

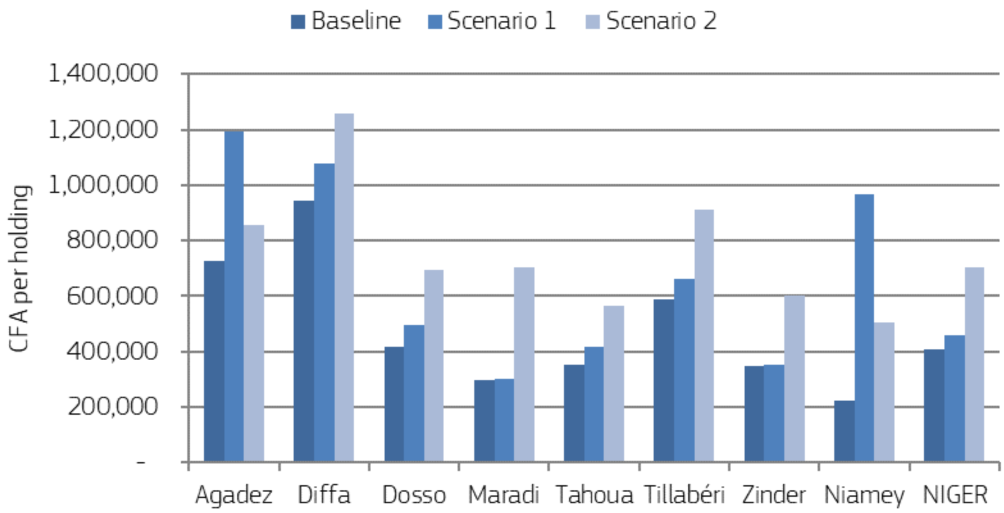
relative terms, this is also because the average starting point (baseline) is very low (on average, an income of 54,000 CFA francs per producer household for the entire dry season cycle).

For the year as a whole, the increase in farm income due to SPIN would be 12%, which represents a significant increase, although the average farm income of the baseline, around 408,000 CFA francs (i.e. 621 euro), is very low. In relative terms, the largest increase would occur in Niamey, followed by the Agadez region. In absolute terms, the average increase per holding would be 51,000 CFA francs for the entire country of Niger. The highest income for the entire year would be seen in the Agadez region, followed by Diffa and then Niamey (see also Figure 7). In Niamey, small holdings would particularly benefit from the SPIN, which explains the important increase in average farm income. At the other extreme, the lowest incomes would be in Maradi and Zinder, which are the two regions that would not benefit as much as others from increased access to irrigation.

Table 9. Effect of the SPIN on farm income per holding, for each region and season

	Agadez	Diffa	Dosso	Maradi	Tahoua	Tillabéri	Zinder	Niamey	NIGER
Rainy season									
Baseline	633,974	746,973	400,875	294,383	219,443	523,905	333,733	154,625	354,805
Scenario 1	801,655	824,172	404,918	294,384	229,177	525,496	333,788	518,868	363,749
Scenario 2	706,912	954,714	454,163	334,992	264,690	664,027	374,148	244,475	420,697
Dry season									
Baseline	94,497	197,109	16,194	1,036	134,568	65,046	13,617	70,320	53,902
Scenario 1	393,514	252,163	91,035	9,698	186,028	136,958	19,070	447,492	95,873
Scenario 2	148,549	304,091	240,051	370,627	302,597	248,883	227,484	258,676	281,795
Entire year									
Baseline	728,471	944,082	417,070	295,420	354,011	588,951	347,351	224,946	408,707
Scenario 1	1,195,169	1,076,335	495,953	304,082	415,205	662,453	352,859	966,359	459,622
Scenario 2	855,461	1,258,806	694,214	705,620	567,287	912,910	601,632	503,151	702,492

Figure 7. Simulation of the effects of the SPIN on farm income per holding



The holding typology allows the above results to be analysed from another perspective (see **Table 10**). It shows that the farm income of small traditional holdings, in the baseline, is particularly low (168,500 CFA francs per year). These holdings are characterised by low land productivity due to environmental constraints and a very limited endowment in production factors. The cropping system of millet, sorghum and cowpea, on which these holdings mainly rely, generally suffers from low yields, not only for agro-climatic reasons, but also due to limited use of inputs and improved varieties as a result of limited financial capacity. Ultimately, these farm households are often locked in a vicious cycle of underinvestment – low yields – low income. Consequently, access to irrigation offers a unique opportunity to escape from this negative spiral, access off-season crops and benefit from the resulting increased income. The SPIN modelling (Scenario 1) shows that these households could increase their income by more than 30% thanks to accessing small-scale irrigation. In relative terms, this category of household is the one that would benefit most from the SPIN, although they would remain the poorest in absolute terms with an annual farm income of 221,000 CFA francs (i.e. an increase of 52,000 CFA francs). In addition, we note that these holdings would also be the ones to benefit most from an extended SPIN programme, such as that represented by Scenario 2. In this case, small traditional holdings would see their income increase by over 150% and larger traditional holdings by 70%.

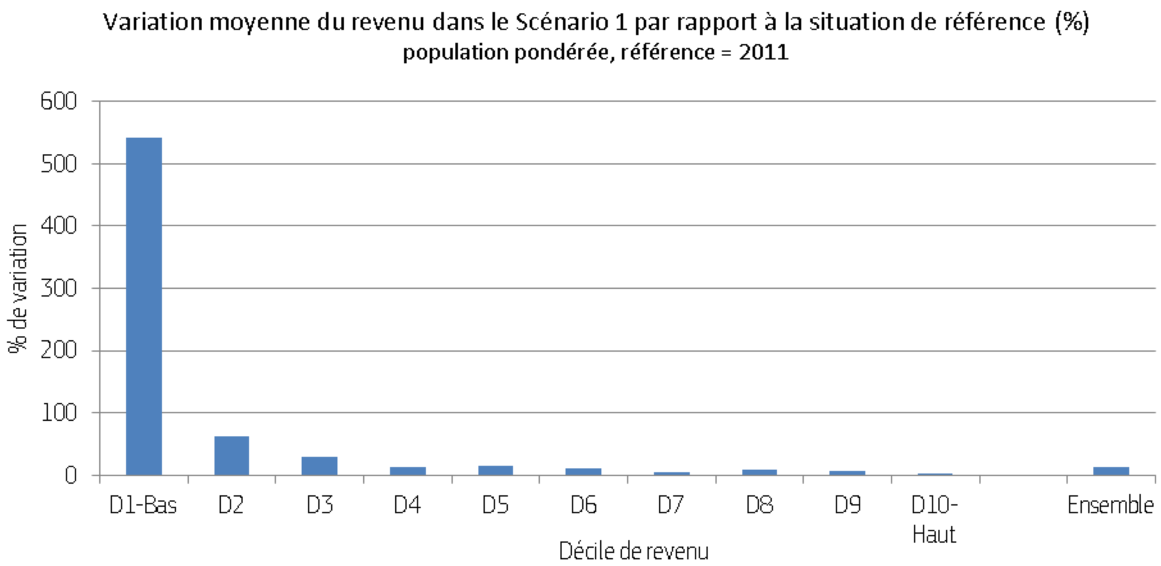
The effect on farm income would also be very significant for diversified holdings (type 5, +29%). However, it would be less so for holdings focusing on cash crops (type 3, +14%), whose income in the baseline is slightly higher than for diversified holdings. Cash crop holdings would be particularly constrained by their labour supply as the agricultural activities that they already carry out (cultivation of rice and groundnut for example) are relatively labour-intensive. In such production systems, labour becomes a limiting factor when turning to the market garden crops permitted by irrigation. This same constraint also applies to market garden holdings, which are the ones that would benefit least from the implementation of SPIN according to our simulations. Their income would increase by only 4%. However, they are already, according to the baseline, the ones that generate the most wealth, and by a long way. Implementing the SPIN would not change this order at all, although it would reduce the gap between the various categories of Nigerien holding.

Table 10. Effect of the SPIN on farm income by type of holding

	Baseline	Scenario 1	Scenario 2
Type 1 – Small holding with traditional crops	168,567	220,978	427,319
Type 2 – Large holding with traditional crops	499,836	503,633	850,959
Type 3 – Holding with non-traditional and cash crops	522,889	596,768	808,103
Type 4 – Market garden holding	1,717,023	1,788,447	1,847,925
Type 5 – Diversified holding	461,532	594,905	741,750

Based on these findings regarding the potential losers and winners from the SPIN in terms of income, we can look at the redistributive effects that this irrigation access policy might have at farm household level. For this purpose, we ranked all the households in the sample by decile[2], according to their farm income in the baseline. **Figure 8** therefore shows the average increase in farm income as a result of implementing the SPIN for each decile of farm income. It is clear that this programme is very conducive to reducing farm income inequalities. Farm households in the bracket of the poorest 10% of households in the baseline (farm income less than 66,000 CFA francs) are the ones that would see their income increase the most due to the access to irrigation enabled by SPIN. Accordingly, their average farm income would be multiplied by more than 6 in Scenario 1. For the 10% of households in the next income bracket (second decile, D2, farm income between 66,000 CFA francs and 124,000 CFA francs per year), the increase would be around 62%. However, for households in the bracket of the richest 10% (farm income above 626,600 CFA francs per year), the increase in farm income would only be 1%.

Figure 8. Effect of SPIN on the redistribution of farm income

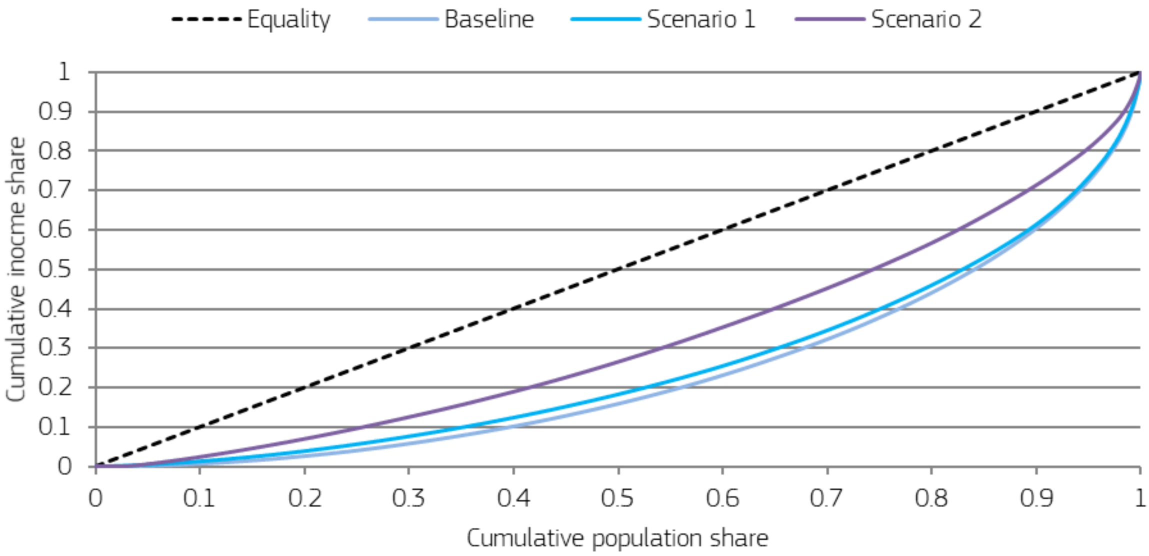


The results of the SPIN modelling also allow the Gini coefficient of farm income distribution to be calculated for all holdings in Niger. The Gini coefficient measures the level of inequality in the distribution of income in a population. It ranges between 0 and 1 (or between 0% and 100%) and increases with the inequality of the distribution. A perfect distribution therefore corresponds to a Gini coefficient of 0. In the case of the farm income of Nigerien households, the Gini coefficient of the baseline is 0.50. Implementing SPIN (Scenario 1)

(2) The ranking by income decile is obtained by sorting all households according to their income and then dividing the population of households into 10% brackets. The first decile therefore corresponds to the poorest 10% of households, the second decile to the next 10% based on income, etc. It is then possible to calculate, for each decile, the average income of the households in that decile.

would result in a Gini coefficient of 0.45, i.e. a reduction of 4.65 points. These results are therefore in line with previous observations and show that SPIN would have a clear positive effect on inequalities in the rural areas in Niger. Furthermore, **Figure 9** shows the Lorenz curve of the distribution of farm income in the baseline and for the SPIN simulation (Scenario 1 and 2). In Scenario 2, the Gini coefficient would reduce by a further 15 points to 0.34, indicating a more equal distribution of farm income within the rural population.

Figure 9. Effect of the SPIN on the Lorenz curve of farm income of Nigerien holdings



All these results therefore confirm that increasing the irrigable area in Niger would have positive effects on the distribution of income and on the reduction of income gaps, as already indicated by the analysis of the impact on the farm income of the various types of holding.

4.2.3 Effect of SPIN on labour demand

The results of the SPIN modelling also allow the impact of this programme on labour demand in Nigerien agriculture to be calculated. Once again, the effects are particularly marked in the dry season and reflect the changes to the cultivated area described above. Nationally, SPIN would increase labour demand by more than 55% in the dry season, which is higher than the 44% increase in the area cultivated in this season. This is explained by the significant labour needs of market garden crops, which are the main off-season crops. This additional labour demand corresponds, in the dry season, to an extra 13 million working days, i.e. in full-time equivalent, to around 59,600 more jobs. Given the current context of the labour market in Niger and the high rate of emigration, job creation is therefore another positive aspect to be credited to the SPIN. The seasonality effect is also important. If we take the example of the Agadez region, the SPIN would create over 2,400 jobs in the dry season, with another 11,900 in the Tillabéri region and 24,000 in the Tahoua region. These new jobs could help to limit the temporary migration of many farmers, mostly the youngest, which is necessary due to the lack of sufficient agricultural work during this season. For both production seasons as a whole, the extra work created by implementing the SPIN amounts to 15 million working-days, i.e. around 70,000 full-time jobs.

In Scenario 2, namely the extended SPIN, the additional labour demand would be even greater, with over 278,000 extra jobs being created across both seasons. It is therefore clear that access to irrigation would result in more labour demand and therefore more jobs created in the agricultural sector.

Table 11. Effects of the SPIN on labour demand in agriculture (in thousands of working days)

	Agadez	Diffa	Dosso	Maradi	Tahoua	Tillabéri	Zinder	Niamey	NIGER
Rainy season									
Baseline	1,551	22,597	80,264	136,269	105,204	142,469	160,187	1,742	650,283
Scenario 1	1,763	23,435	80,545	136,269	105,411	142,550	160,193	2,375	652,541
Scenario 2	1,608	23,839	81,506	136,421	105,646	144,890	160,186	1,838	655,934
Dry season									
Baseline	189	4,011	1,570	87	9,748	5,211	2,449	643	23,909
Scenario 1	715	4,830	4,076	418	15,003	7,837	2,919	1,228	37,026
Scenario 2	275	5,227	8,382	11,321	22,325	12,870	18,318	758	79,475
Entire year									
Baseline	1,740	26,609	81,834	136,356	114,952	147,680	162,636	2,385	674,192
Scenario 1	2,477	28,265	84,621	136,687	120,414	150,387	163,112	3,604	689,567
Scenario 2	1,884	29,066	89,887	147,742	127,971	157,760	178,503	2,596	735,409

4.3 Impact of implementing the SPIN on poverty

Beyond the economic indicator of farm income, it is important to measure the effect that implementing the SPIN would have on income poverty and food insecurity.

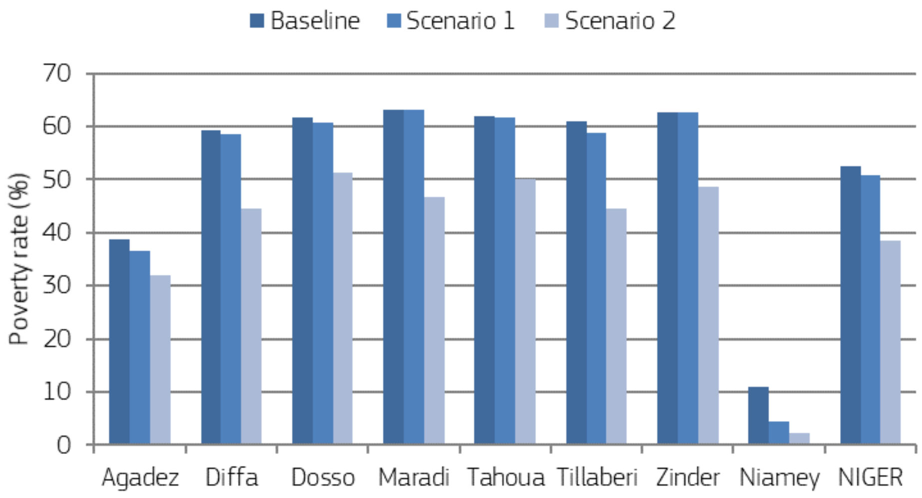
We measured income poverty by using the income thresholds per individual calculated based on the 2011 LSMS-ISA (INS, 2011) and by adjusting our figures to the official poverty rate. For rural households in the agricultural zone, the extreme poverty threshold is set at 150,000 CFA francs per person per year or 410 CFA francs per day. The poverty threshold is twice the extreme poverty threshold, i.e. 300,000 CFA francs per person per year or 820 CFA francs per day. Using these figures, we were therefore able to determine, for each household in our sample, its position in relation to the poverty lines and therefore the poverty rate of each region in the baseline and the SPIN simulation scenarios[3]. The results are shown in **Figure 10** and **Figure 11**.

Nationally, implementing the SPIN would reduce the poverty rate from 52.4% to 50.8% of rural households. This would therefore be a slight improvement, although it is clear that the issue of poverty would not be solved only this way. However, the extended SPIN (Scenario 2) would further reduce the rural poverty rate, which would fall to 38%, i.e. a reduction of nearly 14 points, which, in terms of poverty, is far from negligible. It would be in the Niamey region that rural poverty would reduce the most (from 11% to 4% of the rural population) due to the significant relative increase in irrigated area in this region in comparison with the baseline.

The improvement prompted by the SPIN would be slightly more marked in terms of extreme poverty. The development of small-scale irrigation infrastructure would reduce the extreme poverty rate of rural households from 46% to 43%, i.e. a reduction of 3 percentage points in Scenario 1. In the Agadez region, the SPIN would almost halve the extreme poverty rate. The improvement would also be significant in the Diffa region. Logically, the extended SPIN scenario would result in an even more drastic reduction in extreme poverty (see **Figure 11**).

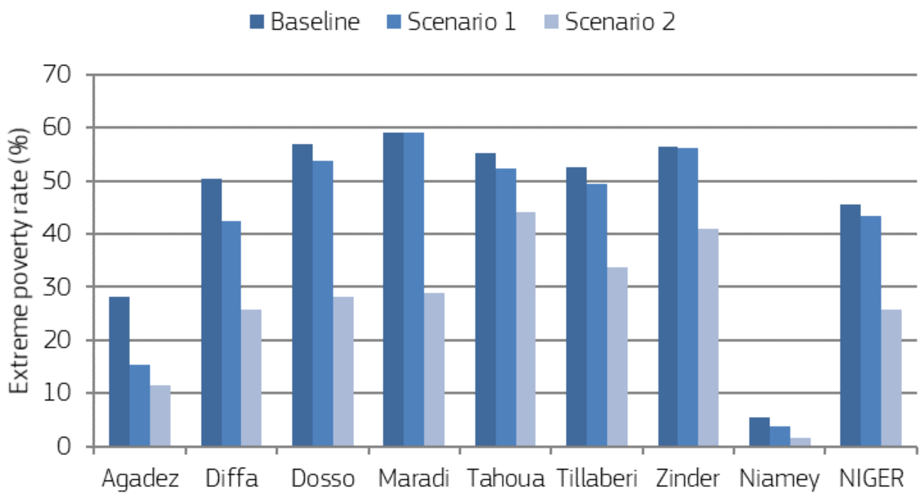
([3]) Note that for the purpose of this work, poverty rates were calculated using the sum of farm income and all other income of the households in the sample, and not using food and non-food expenditure figures, as is usually the case with consumption surveys. This results in poverty incidence figures that differ slightly from those that are found elsewhere, being the methodology quite different. Still, the results of our calculations are relevant to the purpose of our analysis that consists in showing the impact of the SPIN on these indicators, and not to precisely quantifying rural poverty in Niger.

Figure 10. Effect of the SPIN on the poverty of farm households



Note: The poverty threshold used for these calculations is 820 CFA francs per person per day, i.e. 300,000 CFA francs per year (INS, 2011).

Figure 11. Effect of the SPIN on the extreme poverty of farm households



Note: The extreme poverty threshold used for these calculations is 410 CFA francs per person per day, i.e. 150,000 CFA francs per year (INS, 2011).

5 Conclusions

This report presents the results of an assessment of the impacts that a small-irrigation development programme such as the SPIN could have on Nigerien farm households. Using a mathematical programming model that reproduces the behaviour of these households, it was possible to estimate their likely response to the implementation of the SPIN. The SPIN modelling allows the changes in area, production, income generation and poverty reduction that would result from this programme for each of the 2,322 modelled farm-households to be analysed and then extrapolated to the entire Nigerien agricultural sector.

The results of simulating the SPIN are particularly conclusive and seem to endorse the central role of this programme, part of the larger 3N Initiative. Indeed, if the target of increasing the irrigated area, which is currently around 106,000 hectares, to 153,000 hectares were achieved, this would result in significant benefits for a large number of farmers. Accordingly, the average income of households would increase by more than 12%, which represents an average additional income of 51,000 CFA francs for each Nigerien farm household. Furthermore, the results of the simulations show that SPIN would also have a slight positive effect on income inequality between holdings. The Gini coefficient would therefore reduce from 50% to 45%. SPIN would particularly benefit small traditional holdings, which currently mainly rely on a millet-sorghum-cowpea cropping system. These holdings are often locked in a 'poverty trap' – low income, low investment – from which access to small-scale irrigation would allow them to escape by offering them new opportunities for production and diversification of their income.

Lastly, the successful implementation of SPIN could reduce the rural poverty rate by 1.6 points (and 2.1 points for extreme poverty). The SPIN therefore represents a unique opportunity for the Nigerien agricultural sector. To complete the analysis, we also attempted and estimated the cost of this programme. In total, the cost of the required investment would be between 47 billion CFA francs and 189 billion CFA francs (i.e. between 72 million and 288 million euros), which is a considerable sum. However, compared to the generated benefits, it may seem to be justified. This sum would be split between the State, donors and producers, with the latter assuming 60% of the investment cost, with support from the banking sector.

The SPIN simulation results presented in this report are the outcome of extensive work that aimed to mathematically reproduce how Nigerien holdings operate. However, it should be noted that the methodology used to carry out this simulation is subject to a number of limitations. For instance, the physical water availability, as well as the actual cost of installing the irrigation infrastructure for each holding, are not taken into account in the model. Despite these limitations inherent in any ex-ante modelling exercise, the results presented in this study provide an overview of the undeniable benefits of small-scale irrigation for Nigerien farm households.

Among the assumptions made in order to estimate the effects of small-scale irrigation, we assumed that the programme would be accessible to the largest possible number of producers and, therefore, that no obstacles would prevent a producer from accessing irrigation if he or she wanted to do so. This is clearly an optimistic view of reality, which may lead to an overestimation of the effect. However, all the stakeholders involved in implementing the SPIN shall work towards this objective. Accordingly, a programme as ambitious as the SPIN cannot succeed without support for producers from an appropriate, effective and well-organised farm advisory service. Another key element not taken into account in our analyses, is the vital role that the banking sector should play in financing the infrastructure and supporting project developers. Failing so would seriously hinder the capacity of smallholders to access the programme. Professional organisations must also enable farmers to organise themselves in an efficient way in order to reduce their production costs and facilitate the marketing of their production. Lastly, the State must take every possible step to ensure that producers who have opted for small-scale irrigation find a favourable economic environment, allowing them in particular to easily access input and product markets, agricultural extension services, infrastructure maintenance and repair services, among other.

We are hopeful that all these conditions will be met so that small-scale irrigation in general and the SPIN in particular become a key element of the vital transformation of the Nigerien agricultural sector.

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List of abbreviations

ANPIP	*Association Nigérienne de Promotion de l'Irrigation Privée* (Nigerien Association for the Promotion of Private Irrigation)
CAPEG	*Cellule d'Analyse des Politiques Publiques et Evaluation de l'Action Gouvernementale* (Public Policy Analysis and Government Action Evaluation Centre)
JRC	Joint Research Centre of the European Commission
ECVMA	*Enquête sur les Conditions de Vie des Ménages Agricoles* (Living Standards Measurement Study - Integrated Surveys on Agriculture)
FSSIM-Dev	Farm System Simulator for Developing Countries
I3N	*Initiative 3N 'Les Nigériens Nourrissent les Nigériens'* (3N Initiative 'Nigeriens Nourishing Nigeriens')
INRAN	*Institut National de la Recherche Agronomique du Niger* (National Agricultural Research Institute of Niger)
INS	*Institut National de la Statistique* (National Statistics Institute)
LSMS-ISA	Living Standards Measurement Study - Integrated Surveys on Agriculture
PDES	*Plan de Développement Economique et Social* (Economic and Social Development Plan)
PI	*Petite Irrigation* (Small-Scale Irrigation)
GDP	Gross Domestic Product
UNDP	United Nations Development Programme
PPIP	Projet de Promotion de l'Irrigation Privée (Private Irrigation Promotion Project)
SPIN	Stratégie pour la Petite Irrigation au Niger (Small-Scale Irrigation Strategy in Niger)
TS4FNS	Technical Support for Food and Nutrition Security
USD	US dollar

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