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Innovation for Sustainable Agricultural Growth in Mali

PARI

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About this study

In 12 African countries and India Green Innovation Centers (GICs) have been established under the ‘‘One World, No Hunger’’ Initiative (SEWOH) of the German government and other investors. The aim of the GICs is to promote agricultural innovation, improve food and nutrition security and build sustainable value chains in the agri-food sector of these countries. The Program of Accompanying Research for Agricultural Innovation (PARI) has been providing independent research to the SEWOH since 2015. PARI is led by the Center for Development Research (ZEF) at the University of Bonn in close collaboration with the Forum for Agricultural Research in Africa (FARA) and its network of national and regional partners in Africa, the African Growth and Development Policy Modeling Consortium (AGRODEP) facilitated by the International Food Policy Research Institute (IFPRI, Africa Office) and other partners in Germany and India. This country dossier offers a situation analysis of the current state of the agri-food sector, related policies and existing agricultural innovations. It thereby provides basic background knowledge necessary to make fruitful investments in line with the country‘s policies and its potentials, and to find promising partners for development cooperation.

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Acronyms/Abbreviations

BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung / German Federal Ministry of Economic Cooperation and Development
CAADP	Comprehensive African Agriculture Development Programme
CNRST	Centre national de la recherche scientifique et technologique" National Centre of Scientific & Technological Research
CPS	Cellule de Planification et de Statistique / Planning and Statistics Unit
CSCRP	Cadre Stratégique pour la Croissance et la Réduction de la Pauvreté / Strategic Framework for Growth and Poverty Reduction
DHS	Demographic and Health Survey
DNPIA	Direction Nationale des Productions et des Industries Animales / National Directory of Animal Industries and Production
ECOWAS	Economic Community of West African States
FAO	Food and Agriculture Organization
FARA	Forum for Agricultural Research in Africa
CFA	Communauté financière d'Afrique / African Financial Community
GDP	Gross Domestic Product
GHI	Global Hunger Index
GIC	Green Innovation Center
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit / German Agency for International Cooperation
GMM	Grands Moulins du Mali / Malian Great Mills
GNI	Gross National Income
IER	Institut d'Economie Rurale du Mali / Institute of Rural Economy of Mali
IFPRI	International Food Policy Research Institute
INTSORMIL CRSP	International Sorghum and Millet Collaborative Research Support Program
IPR/IFRA	Institut Polytechnique Rural de Formation et de Recherche Appliquée / Technical School for Rural Training and Applied Research
KfW	Kreditanstalt für Wiederaufbau / German Development Bank
LOA	Loi d'orientation agricole / Agricultural Orientation Law
MCC	Millennium Challenge Corporation
MIS	Malaria Indicator Survey
NGO	Non-governmental organization
PARI	Program of Accompanying Research for Agricultural Innovation
PDA	Politique de développement agricole / Agricultural Development Policy
PNIP	Programme national d'irrigation de proximité / National Small Scale Irrigation Program
PNIP-SA	Programme National d'Investissement Prioritaire du Secteur Agricole / National Agricultural Priority Investment Program
PNISA	Programme National d'Investissement du Secteur Agricole / National Agricultural Sector Investment Plan
PPP	Purchasing Power Parity
R&D	Research and Development
RCA	Revealed Comparative Advantage
SDDR	Schéma directeur du secteur du développement rural / Master Plan for Rural Development
SNSDI	Study on National Strategy Development for Irrigation
SEWOH	"One World, No Hunger" Initiative
TFP	Total Factor Productivity
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development

USAID EAT	USAID-Enabling Agricultural Trade
WAAPP	West Africa Agricultural Productivity Program
WHO	World Health Organization
ZEF	Zentrum für Entwicklungsforschung / Center for Development Research

1 General background information on the agricultural and food sectors

Mali is a landlocked country with dry land and desert covering 60% of the country. Poverty is a major challenge, particularly in rural regions where most of the people reside. For the past ten years, the Gross Domestic Product (GDP) of the country has increased at a higher rate than the population, but economic performance is poor and highly dependent upon cotton and gold, which generate over half of the total export earnings (IFAD, 2008). The bulk of agricultural production takes place in the southern part of the country. Millet and sorghum production occurs throughout the agricultural zone, and the majority of market surplus is produced in the cotton area of the southeast, which has a monopoly over cotton marketing rights in Mali.

Although the agricultural sector's share of the GDP is less than half, it employs most of the active population. Agriculture remains an important driver of the economy and is the basis for poverty reduction initiatives. Only 22% of the country's large irrigation capacity has been developed, and crop yields remain far below potential (SNSDI[1], 2007). There has been an increase in cereal production over the past two decades, keeping pace with population growth. However, this has been driven by an increase in the area under cultivation, and soils have progressively been degraded as a result. Agriculture is extremely vulnerable to environmental risks and climatic shocks, such as drought, flood, erratic rainfall patterns and locust invasions. Most of Mali's agriculture is dominated by subsistence rainfed farming. The majority of rural inhabitants have limited access to land, and about 68% of farmers cultivate less than 5 hectares of land. Most farms are ill-equipped to adopt modern practices, and farmers do not have access to credit to make the necessary investments. The use of agricultural inputs and mechanization is very limited. Post-harvest handling of crops and livestock products is poor, and processing technologies are largely undeveloped (IFAD, 2008).

The government's Strategic Framework for Growth and Poverty Reduction (CSCRP) 2007-2011 builds on the lessons learned from the first poverty reduction strategy paper 2002-2006. This second phase focuses on the following strategic pillars: (i) boosting economic growth, improving food security and raising the incomes of rural producers by increasing and diversifying food production, (ii) promoting the well-being of poor people by continuing reforms in the social sector. To attain these goals, the framework places emphasis on ensuring the sustainable Management of natural resources, modernizing family farms, and increasingly moving towards a sector-wide approach to agricultural development by expanding productive infrastructure and developing agro-processing. The third phase of the strategic framework covering the period of 2012 to 2017 (adopted in December 2011) focuses on: (i) promoting accelerated, diversified and sustainable growth oriented towards the development of employment and income-generating opportunities, (ii) reinforcing long-term development strategies and equal access to quality social services, (iii) developing the capacity of institutions and promoting good governance.

As a response to the food price crisis in 2008, the government launched an ambitious initiative to double rice production, which has since been extended to other products, such as maize and wheat (IFAD, 2008). In October 2009, the government adopted a national agricultural sector investment program, with the targets of sustaining 6% growth in agriculture and of stabilizing the output of food staples (cereals, coarse grains, and livestock). This was to be met by maintaining high yields in the short term, and diversifying agricultural exports in the long term.

The Government of Mali implemented a broad range of reforms aimed at transforming the economy by relying more on the private sector and market processes to allocating the countries resources. The reforms involved dismantling and selling state enterprises, which permitted the private sector (including independent farmers and trader organizations) to compete in areas formerly reserved for the state, and removing many barriers to trade, both domestically and internationally.

[1] Study on National Strategy Development for Irrigation

Mali's capacity for research into agricultural innovation relies on its substantial human resources pool, recruited both at the national and international level. Many donor-supported projects contribute to the pool of experts working towards technology generation, dissemination and adoption.

There are many opportunities to develop innovation in Mali's agricultural sector. Interventions should focus on improving food security and incomes by increasing and diversifying the output of smallholder farmers and agribusiness producers, while introducing and reinforcing sustainable land and water management practices. The interventions should target productivity increases for smallholder agricultural and agribusiness producers in specific production systems, including irrigated rice and vegetables, rainfed cereals, cowpea, fodder and livestock. This could be achieved by: (i) introducing improved agricultural technologies and agricultural services, (ii) modernizing smallholder farming systems and supply chains, (iii) promoting sustainable land and water management practices, (iv) investing in small and large-scale irrigation, (v)increasing arable land usage, (vi) building the capacity of stakeholders at all levels, especially women and young people, and helping to develop the capacity of farmer organizations to deliver technical and economic services to producers and participate in local development processes, (vii) increasing access to rural financial services, which will enable farmers to increase and diversify agricultural production thus improving household food security and living conditions (IFAD, 2008).

In twelve African countries, including Mali, Green Innovation Centers (GICs) have been established in selected regions under the ''One World, No Hunger'' Initiative (SEWOH) of the German government and other investors. The aim of the GICs is to promote agricultural innovation, improve food and nutrition security and build sustainable value chains in the agri-food sector. The selected value chains in Mali are rice, (Irish) potato (production of planting material & tubers), vegetables, and fruit (mango). These crops were selected based on: production, preservation, processing and marketing of potato, a value chain dominated by women, and a high potential for the production and marketing of vegetables, fruit and rice. The focal areas of the initiative include Koulikoro, Sikasso, Kayes, Mopti and Ségou.

1.1 Pan-African policies and strategies

Mali signed its Comprehensive African Agriculture Development Programme (CAADP) Compact in October 2009. Mali is one of the few West African countries that met the CAADP goal of allocating 10% of the national budget to agriculture. The country has also surpassed the 6% CAADP agricultural GDP growth target 4 out of 10 years of the Compact. In addition, the government allocated at least 10% of the national budget to agriculture 6 out of 10 years (see Table 10).

Mali has successfully increased the quantity of fertilizer applied per hectare from an average of 9kg/ha to 50kg/ha, as directed by the decision to do so taken by the Economic Community of West African States (ECOWAS) heads of States in Abuja in 2006. In fact the government subsidized fertilizer at 50% since 2008.

1.2 National (and regional) policies and strategies

Key strategies and government priorities for agricultural and rural development:

The Government of Mali has sought to develop a model of agricultural and rural development based on redistributive growth and high added value that takes macroeconomic realities into account and will implement it in an evolutionary sequence of five-year frameworks.

a. Poverty Reduction Strategy Plan

The Poverty Reduction Strategy Plan was setup in 2002 and ran for five years and was then replaced in 2007 by the Strategic Framework for Growth and Poverty Reduction (CSCRP), which framed and supported the implementation of broad strategic directions to end poverty. The CSCRP describes the policies and programs that the country intends to implement so as to "promote growth at an annual

rate of 7% and reduce poverty (Ministry of Agriculture, 2007)" and accelerate progress on the Millennium Development Goals. One of the three pillars of the CSCRP is to strengthen the productive sectors of the economy, with particular emphasis on the rural and agricultural sector (MSU, 2011). The specific focus areas of the CSCRP include:

- Value addition, diversification and better marketing of rural products;
- Water availability and water control;
- Financing of agriculture;
- Access to inputs;
- Protection and preservation of the environment (urban and rural);
- Access to land;
- Plant protection;
- Technical supervision and accountability of rural producers (Ministry of Agriculture, 2007).

The policy guidelines specific to rural and agricultural development have been formulated in a more precise framework, the foundations of which were laid in 1991 at the Convention of the future of country side. These have resulted in the development of the Master Plan for Rural Development (SDDR), adopted in 1992 and renewed for the period 2000-2010 (MAFAP, 2012). However, no budgeted action plan was created for the implementation of programs and mechanisms for the sector recommended by the SDDR's general objectives (Ministère de l'Agriculture, 2007a).

b. Agricultural Orientation Law (LOA)

In 2006, the Malian Government adopted an Agricultural Orientation Law (LOA), with the objective to "determine and conduct the long-term policy of agricultural development in Mali" (RoM, 2006). The LOA covers all economic activities in the agricultural sector, both rural and suburban, aiming to make this sector the engine of the national economy and to promote "sustainable, diverse, modern and competitive agriculture, placing farmers in the center of the process" (RoM, 2006 pg 11). The LOA therefore advocates restructuring and modernizing medium and large family farms, making them competitive and integrating them into the sub-regional economy, thus boosting employment in rural areas. This requires a distancing and disengagement of the state through decentralization and privatization, and greater consultation with stakeholders in the sector. The LOA has been implemented in accordance with the Common Agricultural Policy of ECOWAS and CAADP's recommendations. The strategic framework of the LOA is the Agricultural Development Policy (PDA) from 2011 to 2020 and the Agriculture Land Policy. The PDA is the subject of the first article of the LOA; the PDA translates its vision in a "concrete and quantified" way. The PDA is intended to be more unifying and more operational than the SDDR. This is why a tool for planning and monitoring/evaluation was developed: the National Agricultural Sector Investment Plan (PNISA). It will bring together all national investment plans, programs and projects and interventions relating to the agriculture and food sector in Mali. Several other strategies and major programs for different fields of activity (sanitation, energy, health, rice, etc.), are also integrated within the PDA.

c. Agricultural Competitiveness and Diversification Project

Effective as of April 2006, this program, which was launched by the Government of Mali and supported by the World Bank, aims to promote commercial agriculture as an alternative to subsistence agriculture. It provides an opportunity for professionals in the agricultural sectors to increase their yields and revenue.

d. Agricultural Diversification Project

This program aims to address the problems that hinder the growth of the agro-industry, a sector in which Mali enjoys a comparative advantage. Although mango is the most common product, the project also intends to promote papaya and shallot, among other crops, by developing and disseminating techniques that boost productivity and competitiveness of farms and rural processing companies

(IFAD, 2008). For example, through this program, farmers learn conservation methods and irrigation techniques specific to each crop.

e. The West Africa Agricultural Productivity Program (WAAPP)

The WAAPP is key to the World Bank's support strategy for Mali and to its support for increased regional integration in West Africa. In addition, it is firmly anchored in the New Partnership for Africa's Development and the ECOWAS agricultural policy. Achievements of the first phase of the WAAPP were a 30% crop productivity increase and a 34% increase in revenues for participating farmers. The period between two harvests has also been shortened, a result which is already having a significant impact. With the support of the project, Mali is strengthening its seed systems as well as its research and technology transfer systems in order to provide comprehensive support for the implementation of the National Agricultural Investment Program and to boost the resilience of farming and pastoral communities. The integrated sub-regional aspect of the program, which constitutes one of the program's biggest strengths, also enables Mali to benefit from innovative technologies and techniques developed in the other WAAPP beneficiary countries.

One of these innovative techniques is the introduction of new, more resilient varieties of tomatoes which allow farmers to maintain steady production levels during the rainy season, when tomatoes are in short supply in the markets thus commanding higher prices. The second phase of the program will provide input kits, nucleus breeding programs, motor-pumps, and grafted jujube trees and date palm plants to communities in northern Mali who have been greatly affected by the crisis (Diarra, 2014).

f. National Agricultural Sector Investment Plan (PNISA)

In March 2015, the government has prepared and adopted the ambitious National Agricultural Sector Investment Plan (PNISA) in order to implement the LOA. . This plan runs from 2015 to 2025, and the European Union and others partners intend to support it implementation.

In the framework of the PNISA, the major programs being implemented are:

1. The National Small Scale Irrigation Program (PNIP)

PNIP is a broad national strategy to support the development of small scale irrigation systems in Mali. The ministry of agriculture received support from the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ), the German international development agency, between 2008 and 2012 in the preparation of this program. PNIP was adopted by the Government in March 2012. Since then, the German Government (through the BMZ) and others donors (Canada, the European Union, the United States, etc.) have helped with its implementation. Assistance from the German government is provided through:

- The GIZ, which provides technical assistance to the Ministry of Agriculture at the national and local scale for capacity building.
- *Kreditanstalt für Wiederaufbau* (KfW), a government development bank, which finances the construction of small scale irrigation infrastructure projects.

The GIZ closely collaborates with the Rural Polytechnic Institute (IPR/IFRA)[2] in Katibougou and others training centers (Samanco, Zanblara and Niono) and offers technical support to implement the "Green Innovation Centers" in the framework of SEWOH initiative. The GIZ also funds the field work of some masters and doctoral students who work on some selected value chain (rice, potato, etc).

KfW has financed many small scale irrigation infrastructure projects in Mali. Theses infrastructure projects have increased food security, reduced poverty, increased the income of local farmers and have also have some impacts on hydrological dynamics of inland valley.

[2] The West African Science Service Center on Climate Change and Adapted Land Use program supported by ZEF also collaborated with IPR/IFRA.

There is therefore scope for collaboration with GIZ and KfW for research on common themes and knowledge sharing.

2. Large Scale Irrigation Program in "Office du Niger"

This program is prepared and given support by the KfW and others donors. The KfW is also interested in studying similar issues, such as food security, poverty reduction, and income of local farmers. With the collaboration of the KfW, support could be extended to masters and doctoral students investigating these issues.

1.3 Data on food and nutrition security in Mali and GIC region

The following section includes information about important socio-economic and agricultural indicators and data on diet quantity, diet quality and nutrition status.

1.3.1 Socio-economic and agricultural data

Table 1: Selected national economic and health-related data

Indicator	Value	Year
Population, total	15,768,227	2014
Population growth (annual %)	3.0	2014
Rural population (% of total population)	61	2014
GDP per capita, PPP (constant 2011 international $)	1,653	2014
GNI per capita, PPP (constant 2011 international $)	1,587	2011
Poverty headcount ratio at $2 a day (PPP) (% of population)	79	2010
Poverty headcount ratio at $1.25 a day (PPP) (% of population)	51	2010
Poverty headcount ratio at national poverty lines (% of population)	44	2010
Rural poverty headcount ratio at national poverty lines (% of rural population)	51	2010
Agricultural land (% of land area)	34	2012
Agricultural irrigated land (% of total agricultural land)	no data	
Agriculture value added per worker (constant 2005 US$)	842	2012
Agriculture, value added (% of GDP)	42	2012
Access to electricity, rural (% of rural population)	12	2012
Employees, agriculture, female (% of female employment)	64	2006
Employees, agriculture, male (% of male employment)	68	2006
Employment in agriculture (% of total employment)	66	2006
Literacy rate, adult total (% of people ages 15 and above)	34	2011
Ratio of female to male secondary enrollment (%)	80	2013
Mortality rate, under-5 (per 1,000 live births)	123	2013
Maternal mortality ratio (modelled estimate, per 100,000 live births)	550	2013

Source: World Bank, data.worldbank.org/country
Note: GDP refers to Gross Domestic Product; GNI refers to Gross National Income; PPP refers to Purchasing Power Parity

1.3.2 Data on diet quantity, diet quality and nutrition status

Data on diet quantity, diet quality and nutrition status are relevant for assessing food and nutrition security. Dietary energy supply per capita – a measure of diet quantity – is more than adequate in Mali; It exceeds the average dietary energy requirement of the population by more than one third (Table 2). The incidence of food over-acquisition is high; the United Nations Food and Agriculture Organization (FAO) estimates that almost half of the population tends to regularly acquire food in excess of their dietary energy needs. The prevalence of undernourishment was at a moderate level in the early 1990s

and has decreased modestly since then, by 13 percentage points overall, whereas increases in the prevalence of food over-acquisition were more pronounced (Figure 1).

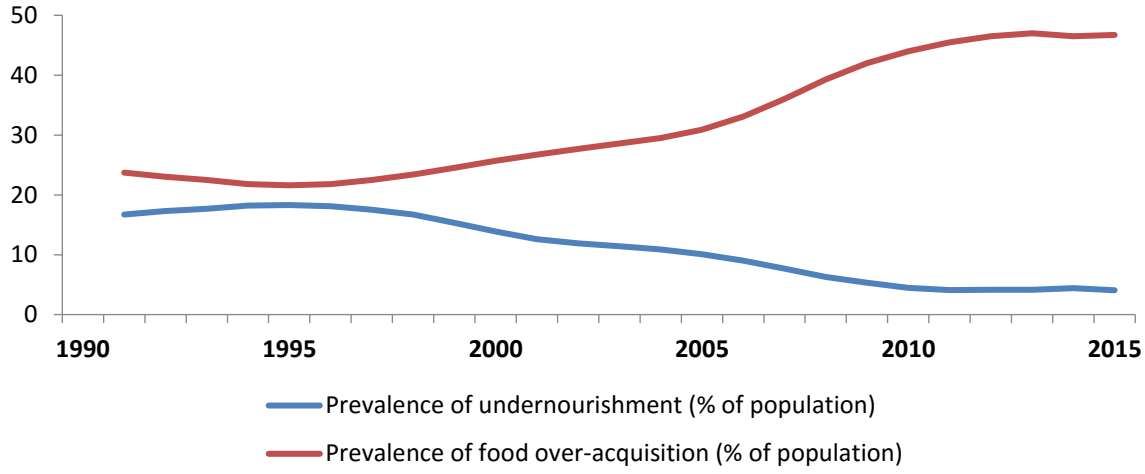
Table 2: Food and nutrition security indicators

Indicator	Value	Year
Diet quantity		
Dietary energy supply (kcal/caput/day)	2856	2014-16
Average dietary energy supply adequacy (% of average requirement)	137	2014-16
Prevalence of undernourishment (% of population)	4	2014-16
Prevalence of food over-acquisition (% of population)	47	2014-16
Diet quality		
Dietary energy supply from cereals, roots and tubers (% of total dietary energy supply)	68	2009-11
Dietary energy supply from carbohydrate (% of total dietary energy supply)	68	2009-11
Dietary energy supply from protein (% of total dietary energy supply)	12	2009-11
Dietary energy supply from fat (% of total dietary energy supply)	20	2009-11
Average protein supply (g/caput/day)	82	2009-11
Average fat supply (g/caput/day)	64	2009-11
Child feeding practices		
Minimum dietary diversity: consumption of 4+ food groups (% of children 6-23 months)	22	2012-13
Consumption of foods rich in vitamin A (% of children 6-23 months)	55	2012-13
Consumption of foods rich in iron (% of children 6-23 months)	49	2012-13
Nutrition status		
Child wasting (% of children under five)	13	2012-13
Child stunting (% of children under five)	38	2012-13
Child overweight (% of children under five)	2	2012-13
Adult overweight and obesity (% of adults 18+ years)	25	2014
Adult obesity (% of adults 18+ years)	7	2014
Vitamin A deficiency (% of children 6-59 months)	66	2013
Anemia in children (% of children 6-59 months)	85	2015
Anemia in women (% of women 15-49 years)	51	2012-13

Source: Cellule de Planification et de Statistique, Institut National de la Statistique, INFO-STAT and ICF International (2014); FAO (2016), and authors' calculations based on FAO (2016); Programme National de Lutte contre le Paludisme, Institut National de la Statistique, INFO-STAT, Institut National de la Recherche en Santé Publique and ICF International (2016); Stevens et al. (2015), quoted in International Food Policy Research Institute (IFPRI) (2015); von Grebmer et al. (2016); World Health Organization (WHO) (2015a)

Notes: Data on child feeding practices, child nutrition status and anemia in women are from the 2012-13 Mali Demographic and Health Survey (DHS), and data on anemia in children from the 2015 Mali Malaria Indicator Survey (MIS). The 2012-13 Mali DHS did not cover the Northern regions of the country (Tombouctou, Gao, and Kidal) because they were occupied by rebel forces at the time of the survey. The households in the Northern regions that could not be interviewed due to the security situation made up less than 10% of the initial, nationally representative sample (Cellule de Planification et de Statistique, Institut National de la Statistique, INFO-STAT and ICF International, 2014). The 2015 Mali MIS also excluded the three Northern regions (Programme National de Lutte contre le Paludisme, Institut National de la Statistique, INFO-STAT, Institut National de la Recherche en Santé Publique and ICF International, 2016). See Annex A for definitions of the indicators.

Figure 1: Prevalence of undernourishment and food over-acquisition (1990-92 to 2014-16)



Source: Authors' presentation based on data from FAO (2016)

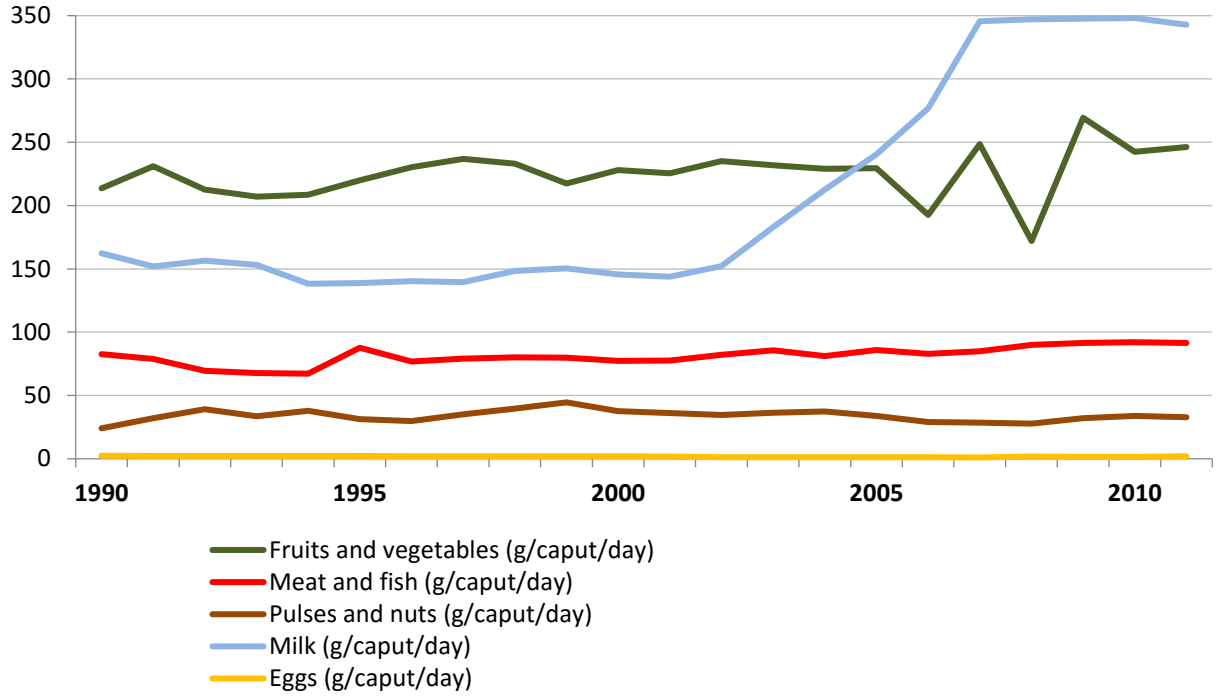
The diet in Mali is predominantly based on starchy staples (mainly rice, sorghum, millet, and maize) that provide more than two thirds of the total dietary energy supply (Table 2). The shares of dietary energy supply from carbohydrates, protein, and fat are well within the recommended ranges of 55-75%, 10-15%, and 15-30%, respectively (WHO, 2003). This means that the diet is balanced in terms of its macronutrient composition. Average protein supply is more than sufficient to meet protein requirements (Table 2; see Annex A for further explanation).

The consumption of sufficient quantities of non-staple foods, such as fruits and vegetables and animal-source foods is essential for a diet that provides adequate amounts of micronutrients. Overall, meat and fish supply has increased very little in Mali since 1990 and was still below 100 g/caput/day in 2011 (Figure 2). Milk supply has more than doubled since 2000 and is now fairly high by African standards, whereas the supply of eggs has remained very low. Pulses and nuts play a relatively minor role in the Malian diet; they contribute to protein supply, but to a lesser extent than milk or meat and fish.[3] Fruit and vegetable supply has not increased much since 1990 and has proved unstable in recent years. The amount of fruits and vegetables supplied in 2011 (about 250 g/caput/day) is considerably below the recommended intake of 400 g of fruits and vegetables per day (WHO, 2003).

A dietary intake study of women of reproductive age in Bamako found that even in the privileged capital city, diets were lacking in multiple micronutrients. The women's intakes of vitamin B12 (a micronutrient found only in animal-source foods), calcium and folate were highly inadequate, and intakes of riboflavin and niacin were moderately inadequate (Martin-Prével et al., 2015).

[3] Source: Food balance sheet for Mali, 2011, from FAOSTAT, accessed 15 Nov, 2016.

Figure 2: Supply of non-staple foods (1990-2011)



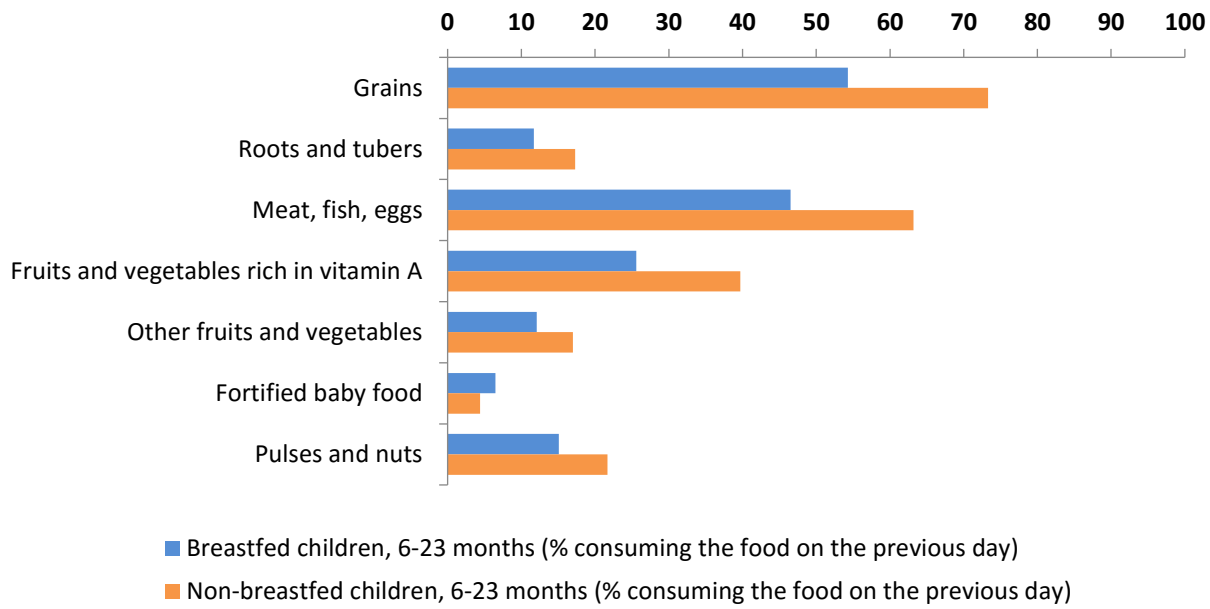
Source: Authors' presentation based on data from FAOSTAT, accessed 07 Oct 2016
Note: Based on their nutrient profiles, pulses and nuts include groundnuts and soybeans, although these foods are classified by FAO as oilcrops. Coconuts are not included among pulses and nuts because they have low protein content.

Infant and young child feeding practices are crucial for children's nutrition and health status and long-term development. Children aged 6-23 months should consume at least 4 out of 7 food groups (minimum dietary diversity) and receive iron-rich foods and foods rich in vitamin A daily. In Mali, infants' and young children's diets fall short of these goals; roughly one fifth achieved minimum dietary diversity, less than half consumed iron-rich foods, and only 55% consumed foods rich in vitamin A on the previous day (Table 2). Both breastfed and non-breastfed children aged 6-23 months were most frequently fed foods made from grains; other, more micronutrient-rich foods such as meat, fish and eggs, and especially fruits and vegetables rich in vitamin A, as well as pulses and nuts, were consumed by much smaller proportions of children (Figure 3). Fortified baby foods, which can compensate for a lack of micronutrients in the diet, were consumed by less than 10% of breastfed and non-breastfed children.

Stunting and wasting are indicators of chronic and acute child undernutrition, respectively. In Mali, stunting in children has barely improved since the late 1980s; stunting rates even increased, peaking in 2001, and declined again afterwards. Wasting rates fluctuated and have been higher in recent years than they were in 1987 (UNICEF[4]/WHO/World Bank, 2016; Cellule de Planification et de Statistique, Institut National de la Statistique, INFO-STAT and ICF International, 2014). The prevalence rates of stunting and wasting amount to 38% and 13%, respectively, indicating that both forms of undernutrition constitute moderate public health problems in Mali (Table 2). Overweight in children has risen since the late 1980s, but, according to the latest available data, the prevalence is relatively low.

[4] UNICEF = United Nations International Children's Emergency Fund

Figure 3: Percentage of infants and young children consuming foods from selected food groups (2012-13)



Source: Authors' presentation based on data from Cellule de Planification et de Statistique, Institut National de la Statistique, INFO-STAT and ICF International (2014)
Note: Data are from the 2012-13 Mali DHS, which did not cover the Northern regions of the country due to the security situation (see notes to Tables 2 and 5 for further information).

Overweight and obesity are risk factors for chronic diseases such as diabetes (Must and McKeown 2012). They affect one fourth of adults in Mali (Table 2). Since the mid-1990s, the combined prevalence of overweight and obesity has more than doubled in women of reproductive age, while the prevalence of obesity has almost quadrupled during the same period (Figure 4). The prevalence of underweight, however, has only decreased modestly and still exceeds 10%.[5]

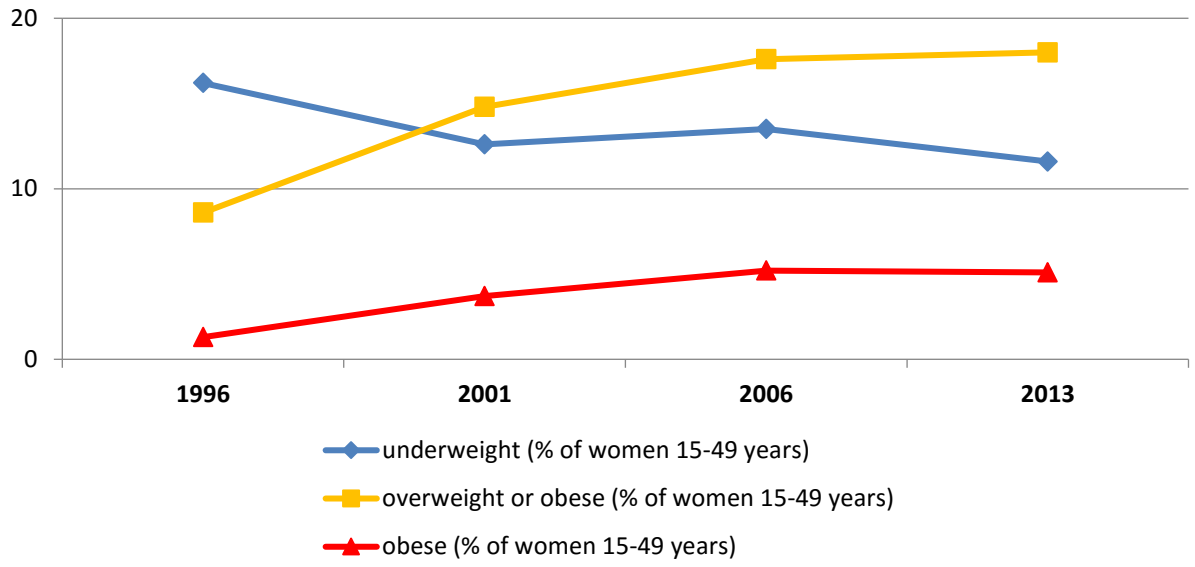
Vitamin A deficiency is a risk factor for blindness and for mortality from measles and diarrhoea in children aged 6–59 months (Imdad et al. 2010; Imdad et al. 2011). In Mali, two thirds of all children in this age group are estimated to be vitamin A deficient (Table 2). Roughly half of all women of reproductive age and more than 80% of children aged 6-59 months suffer from anemia. About half of the global burden of anaemia can be attributed to iron deficiency (WHO, 2015b). Anemia is also caused by malaria, which affects about one third of children aged 6-59 months in Mali. Malaria constitutes a major risk factor for severe anemia in preschool children (Programme National de Lutte contre le Paludisme, Institut National de la Statistique, INFO-STAT, Institut National de la Recherche en Santé Publique and ICF International, 2016).

Regionally disaggregated data are available for indicators of nutrition status and child feeding. The diversity of infants' and young children's diets is particularly low in the Mopti region (Table 3). Children's dietary diversity is much better in the capital city Bamako, as is the proportion of children consuming foods rich in iron and vitamin A. The rates of anemia in children are very high and do not vary much across the GIC regions; it is only Bamako that has a somewhat lower prevalence rate (Table

[5] See Annex A for definitions of overweight, obesity, and underweight. The exclusion of the Northern regions from the 2012-13 Mali DHS is unlikely to bias the trends discussed in this paragraph in a tangible way, since less than 10% of households live in the Northern regions. Furthermore, according to the 2006 Mali DHS, the prevalence rates of underweight, overweight and obesity in women in the North were fairly similar to the national average (see notes to Table 5).

4). The Mopti region has the highest proportion of stunted children, more than twice that of Bamako. Wasting is also highest in Mopti, but the differences across regions are not very pronounced. Regarding overweight and obesity in women, the prevalence in Bamako is more than double than in all other regions (Table 5). Anemia prevalence in women is lowest in Bamako and Koulikoro and differs little across the other three regions.

Figure 4: Underweight, overweight and obesity among women of reproductive age (1996-2013)



Source: Authors' presentation based on data from ICF International (2015), The DHS Program STATcompiler, funded by the United States Agency for International Development (USAID), accessed 12 Sept 2016
Note: The latest data on women's nutritional status are from the 2012-13 Mali DHS, which did not cover the Northern regions of the country due to the security situation (see notes to Tables 2 and 5 for further information).

Table 3: Child feeding practices by region, 2012-13

Share of children 6-23 months consuming:					
4+ food groups		**Foods rich in vitamin A**		**Foods rich in iron**	
Region	**(%)**	**Region**	**(%)**	**Region**	**(%)**
Bamako	35	Bamako	67	Bamako	63
Koulikoro	24	Koulikoro	56	Koulikoro	51
Kayes	23	Kayes	54	Kayes	49
Sikasso	22	Sikasso	54	Ségou	48
Ségou	18	Ségou	51	Sikasso	46
Mopti	10	Mopti	50	Mopti	41

Source: Cellule de Planification et de Statistique, Institut National de la Statistique, INFO-STAT and ICF International (2014)
Notes: Data are from the 2012-13 Mali DHS, which did not cover the Northern regions of the country due to the security situation (see notes to Table 2 for further information). According to the 2006 Mali DHS, in the Northern regions as a whole, the share of children consuming fruits and vegetables rich in vitamin A (not including animal-source foods rich in vitamin A) was 4 percentage points below the national average, and the share of children consuming iron-rich foods was one percentage point above the national average. Data on the share of children consuming 4 or more food groups are not available from the 2006 Mali DHS (Cellule de Planification et de Statistique du Ministère de la Santé, Direction Nationale de la Statistique et de l'Informatique du Ministère de l'Économie, de l'Industrie et du Commerce and Macro International Inc., 2007). GIC regions are marked in red. See Annex A for definitions of the indicators.

Table 4: Child nutrition status by region, 2012-13/2015

Prevalence in children under five:						Prevalence in children aged 6-59 months:	
Stunting		Wasting		Overweight		Anemia	
Region	**(%)**	**Region**	**(%)**	**Region**	**(%)**	**Region**	**(%)**
Bamako	21	Koulikoro	11	Sikasso	1	Bamako	74
Kayes	34	Bamako	12	Bamako	2	Sikasso	85
Koulikoro	40	Kayes	12	Koulikoro	2	Kayes	86
Sikasso	40	Ségou	13	Kayes	3	Ségou	86
Ségou	41	Sikasso	13	Mopti	3	Koulikoro	88
Mopti	47	Mopti	15	Ségou	4	Mopti	89

Source: Cellule de Planification et de Statistique, Institut National de la Statistique, INFO-STAT and ICF International (2014); Programme National de Lutte contre le Paludisme, Institut National de la Statistique, INFO-STAT, Institut National de la Recherche en Santé Publique and ICF International (2016)

Notes: Data on stunting, wasting, and overweight are from the 2012-13 Mali DHS, and data on anemia from the 2015 Mali MIS. These surveys did not cover the Northern regions of the country due to the security situation (see notes to Table 2 for further information). According to the 2006 Mali DHS, the prevalence rates of stunting, wasting, and overweight in children in the Northern regions as a whole were 1-2 percentage points above the national average, whereas the prevalence of anemia in children was 14 percentage points below the national average (Cellule de Planification et de Statistique du Ministère de la Santé, Direction Nationale de la Statistique et de l'Informatique du Ministère de l'Économie, de l'Industrie et du Commerce and Macro International Inc., 2007). GIC regions are marked in red. See Annex A for definitions of the indicators.

Out of all indicators of children's nutrition status, anemia has the highest prevalence rates, followed by stunting (Table 4). This holds for all regions and for the national average. Under the assumption that half of all anemia is due to iron deficiency, iron deficiency anemia in children is of moderate public health significance in Bamako, and of severe public health significance in the other regions.[6] Stunting has mild public health significance in Bamako, severe significance in the Ségou and Mopti regions, and moderate significance in the other three regions, whereas wasting is at a moderate level in all regions. Overweight in children is a mild public health concern only in the Ségou region.

Out of all indicators of women's nutrition status, anemia has the highest prevalence in all regions (Table 5) and consequently also at the national level. The combined prevalence of overweight and obesity exceeds the prevalence of underweight in all regions, yet, the differences are small; Bamako, where more than one third of women are overweight or obese, is the only exception to this rule. Underweight in women continues to be a concern in most regions.

[6] About half of the global burden of anemia is attributable to iron deficiency (WHO 2015b). Since the prevalence of anemia in children in all regions except for Bamako is above 80%, the estimated prevalence of iron deficiency in these regions surpasses 40%, the threshold that indicates a severe public health problem (see Annex A). However, it is possible that less than half of all anemia in children in Mali is caused by iron deficiency, considering the share of children affected by malaria.

Table 5: Women's nutrition status by region, 2012-13

Prevalence in women of reproductive age (15-49 years):							
Underweight		**Overweight + obesity**		**Obesity**		**Anemia**	
Region	**(%)**	**Region**	**(%)**	**Region**	**(%)**	**Region**	**(%)**
Bamako	9	Koulikoro	14	Mopti	3	Bamako	46
Ségou	10	Sikasso	15	Koulikoro	3	Koulikoro	47
Kayes	11	Mopti	15	Sikasso	3	Sikasso	52
Koulikoro	12	Ségou	16	Ségou	4	Kayes	53
Sikasso	13	Kayes	17	Kayes	4	Ségou	55
Mopti	14	Bamako	36	Bamako	15	Mopti	57

Source: Cellule de Planification et de Statistique, Institut National de la Statistique, INFO-STAT and ICF International (2014)
Notes: Data are from the 2012-13 Mali DHS, which did not cover the Northern regions of the country due to the security situation (see notes to Table 2 for further information). According to the 2006 Mali DHS, in the Northern regions as a whole, the prevalence of underweight; overweight and obesity; and obesity in women were 1, 8, and 3 percentage points, respectively, above the national average. The prevalence of anemia in women in the Northern regions was 7 percentage points below the national average (Cellule de Planification et de Statistique du Ministère de la Santé, Direction Nationale de la Statistique et de l'Informatique du Ministère de l'Économie, de l'Industrie et du Commerce and Macro International Inc., 2007). GIC regions are marked in red. See Annex A for definitions of the indicators.

In summary, micronutrient deficiencies and child stunting are the most common and most severe nutrition problems in Mali, although rising overweight and obesity in adults are also a concern. Cereals such as rice, millet, sorghum, and maize are already produced in large quantities and contribute to high dietary energy supply, but the domestic supply of more micronutrient-rich foods needs to be increased to reduce widespread micronutrient deficiencies.[7] Priority should be given to developing value chains for animal-source foods, pulses and nuts, and vegetables and fruits, in particular. The fortification of staple foods (especially of white rice, which is the most important staple in Mali and has low iron and zinc content) and the production of fortified baby foods could be addressed at the processing stage of the value chain. Promoting biofortified staple foods, such as the orange-fleshed sweet potato and orange maize rich in Vitamin A developed by HarvestPlus, would be another option to improve diets in Mali.[8]

In addition, reducing the aflatoxin contamination of foods is necessary to improve food safety in Mali. Aflatoxins are highly toxic substances that are produced by certain types of fungi and can cause acute poisoning, liver cancer, and stunted growth in children (Bhat and Vasanthi, 2003; Gong et al., 2004). Aflatoxin contamination of groundnuts and groundnut products is a major problem for the sector because it poses serious health risks and constrains access to export markets (MAFAP, 2013). Waliyar et al. (2015) found unsafe aflatoxin concentrations in 33-54% of pre-harvest groundnut samples from three study districts, and the contamination increased during storage and in the markets. High aflatoxin levels prohibited the World Food Program from procuring maize produced in Mali in 2011 (Méaux et al., 2013). Aflatoxins were also found in dried vegetables from Mali and from other West African countries (Hell et al., 2009).

With regard to the regions, the nutritional deficiencies in the Mopti region suggest that it should be a priority area for interventions and agricultural innovations. Indicators of child feeding, child undernutrition, underweight in women, and anemia in women and children are much more favorable in Bamako, yet, rates of overweight and obesity in women are also much higher in the capital city than

[7] Raising agricultural productivity for cereals may still be important in order to keep pace with the rising demand, to reduce dependency on rice imports, and to alleviate poverty (e.g. through improvements in rice value chains targeting smallholder farmers, which is an especially commendable strategy if diets and incomes can be simultaneously diversified time through intercropping with aquaculture and horticulture).
[8] See www.harvestplus.org/what-we-do/crops

in other regions. Recent data are not available for the Northern regions, but findings from the 2006 Mali DHS indicate that women's and children's undernutrition were about average in this area, while anemia rates were even lower than at the national level.

Mali is a member of the Scaling Up Nutrition network, a global movement led by 57 countries that aims to end malnutrition in all its forms. See scalingupnutrition.org for more information.

1.4 Data on most relevant crops and value chains

The most relevant crops in Mali primarily include grains (rice, millet and sorghum, maize) and some vegetables. Groundnuts and Bambara nuts are also important. Production and consumption data are provided below.

1.4.1 Production

Table 6: Top 10 crops produced by area, volume and value

Area harvested (ha)		Production volume (tons)		Production value*	
Top 10	**Share of Total (%)**	**Top 10**	**Share of Total (%)**	**Top 10**	**Share of Total (%)**
Millet	29.5	Rice, paddy	19.8	Rice, paddy	10.6
Sorghum	19.8	Maize	15.6	Meat indigenous, cattle	8.7
Maize	11.8	Millet	14.6	Meat, cattle	8.2
Rice, paddy	11.1	Sorghum	10.4	Watermelons	7.2
Seed cotton	9.0	Seed cotton	4.8	Millet	5.9
Groundnuts, with shell	6.2	Groundnuts, with shell	4.7	Milk, whole fresh goat	4.6
Cow peas, dry	5.1	Watermelons	3.5	Maize	4.4
Karite nuts (sheanuts)	1.0	Sugar cane	3.3	Meat indigenous, sheep	4.2
Vegetables, fresh nes	1.0	Sweet potatoes	3.2	Sorghum	4.2
Sesame seed	0.9	Cottonseed	2.9	Meat, sheep	4.1
Rank 18: Potatoes	0.1	Rank 11: Vegetables, fresh nes	2.8	Rank 18: Potatoes	1.5
Rank 25: Onions, dry	0.1	Rank 16: Potatoes	1.4	Rank 25: Onions, dry	0.9
Rank 31: Mangoes, mangosteens, guavas	0.0	Rank 20: Onions, dry	0.6	Rank 38: Mangoes, mangosteens, guavas	0.3
		Rank 21: Mangoes, mangosteens, guavas	0.5		

Data: average 2012-2014, FAOSTAT, accessed 18 January, 2017
* Gross Production Value (constant 2004-2006 million US$), data: average 2011-2013, FAOSTAT, accessed 18 January, 2017
Note: GIC value chains marked in red; nes refers to Not elsewhere specified

1.4.2 Trade

Rice, wheat and sugar and prepared food are the most important goods in import trade. Cotton is the most important export good and accounts for more than 78% of the export volume and nearly 90% of the export value. Sesame seed is also an important export product (6% of the export volume), but contributes little to the total export value (less than 4%).

Table 7: Mali's imports

Import volume (tons)		Import value (US$)	
Top 10	**Share of Total (%)**	**Top 10**	**Share of Total (%)**
Rice – total (Rice milled equivalent)	28.9	Food prep nes	13.5
Wheat	22.0	Rice – total (Rice milled equivalent)	12.5
Sugar refined	10.9	Wheat	11.5
Oil, palm	5.1	Oil, palm	7.0
Flour, wheat	3.4	Milk, whole dried	6.6
Food prep nes	3.3	Sugar refined	6.0
Cottonseed	3.1	Tea	5.9
Fatty substance residues	2.2	Food preparations, flour, malt extract	5.5
Macaroni	1.5	Cigarettes	5.0
Tea	1.3	Flour, wheat	2.9
Rank 11: Potato	1.3	Rank 15: Potato	0.9
Rank 13: Onions, dry	1.1	Rank 21: Onions, dry	0.5
Rank 48: Vegetables, preserved nes	0.1	Rank 46: Vegetables, preserved nes	0.2
Rank 211: Mangoes, mangosteens, guavsa	0.0	Rank 213: Mangoes, mangosteens, guavsa	0.0

Data: average 2011-2013, FAOSTAT, accessed 18 January, 2017
Note: GIC value chains marked in red; nes refers to Not elsewhere specified

Table 8: Mali's exports

Export volume (tons)		Export value (US$)	
Top 10	**Share of Total (%)**	**Top 10**	**Share of Total (%)**
Cotton, carded, combed	49.6	Cotton, carded, combed	62.9
Cotton lint	29.0	Cotton lint	29.0
Sesame seed	6.1	Sesame seed	3.7
Fruit, tropical fresh nes	3.5	Fruit, tropical fresh nes	1.1
Cashew nuts, with shell	1.9	Mangoes, mangosteens, guavas	0.6
Beverages, non-alcoholic	1.4	Cashew nuts, with shell	0.4
Nuts, nes	1.0	Beverages, non-alcoholic	0.3
Mangoes, mangosteens, guavas	0.8	Milk, skimmed dried	0.2
Groundnuts, shelled	0.7	Oil, groundnut	0.2
Maize	0.5	Groundnuts, shelled	0.2
Rank 31: Potatoes	0.1	Rank 36: Rice – total (milled equiv.)	0.0
Rank 57: Rice – total (milled equiv.)	0.0	Rank 42: Vegetables, fresh nes	0.0
Rank 62: Vegetables, fresh nes	0.0	Rank 97: potatoes, frozen	0.0

Data: average 2011-2013, FAOSTAT, accessed 18 January, 2017
Note: GIC value chains marked in red; nes refers to Not elsewhere specified

1.5 National (and regional) innovation system

1.5.1 Research system and organizations

The research system is currently incoherent; there are several research institutions that are scattered among various ministries and regional states. The different institutions have varied functions, both central and personalized, also with financial autonomy, etc.).
Each department considers itself solely responsible for the research activities conducted by the institutions relevant to its mandate. The research institutions planned and carried out their programs independently of one another, without referring either to the National Centre of Scientific & Technological Research (CNRST) or the Ministry of Secondary and Higher Education and Scientific Research (MSHESR), i.e. to the official institutions supposed to coordinate and control research activities at national level.
Research in Mali is 90% externally financed, and this constitutes a major handicap in the execution of national research programs in cases where these do not coincide with the priorities of the fund donors.

1.5.1.1 International

Many international research organizations are involved in agricultural research activities in Mali. Most of these organizations work in partnerships with the National Agricultural Research Institute (IER) on various thematic issues. The prominent organizations include the Sahel Institute, Winrock International, the International Institute of Tropical Agriculture, the World Agroforestry Center, the West Africa Rice Development Association, the International Livestock Research Institute, the Royal Tropical Institute of the Netherlands, the Center of International Agricultural Research Cooperation for Development, and the Institute of Research for Development. The two latter organizations are from France.

Example of Mali and Development Partners' partnership: Mali Feed the Future Strategy
The USAID/Mali Feed the Future Strategy draws upon the expertise acquired through deep, long-term involvement in the agricultural sector, which provides a base for transformational change.
The USAID/Mali Feed the Future strategy:

- It is aligned with and supports the National Agricultural Priority Investment Program (PNIP-SA). It is a government-driven, donor-coordinated process. USAID/Mali will bolster the formation of public and private agricultural sector donor groups by coordinating and complementing their work;
- It is a market-based strategy, which leverages market structures to extend the reach and impact of investments. It builds the capacity of producer organizations and links them with traders and processors to ensure consistent supply and quality standards. It supports value-adding processors with diversifying their offerings, expand markets for products, and ensure price stability for raw materials;
- It focuses only on strategic interventions with a high economic and food security impact. It builds small-scale irrigation systems that have a great potential for success due to investments by the local communities and it complements the Millennium Challenge Corporation's (MCC) work in the rice sector by concentrating on small-scale irrigation systems;
- It builds on past USAID/Mali experience with value chain development by making use of the long-standing relationships with CPS, which is the planning and statistics unit, and the IER/University of Bamako.

1.5.1.2 National

The national institutional arrangement for science and technology in Mali revolves around three major organizations, viz. Ministry of Livestock and Fisheries, CNRST and the Ministry of Secondary and Higher Education and Scientific Research. Under the direct auspices of the ministry of livestock and fisheries, there is the Central Veterinary Laboratory and the Malian livestock Agency. The University of Mali, Bamako, is under the auspices of CNRST, while six research organizations, viz. (i) National Directorship for Metrology, (ii) National Centre for Fruit Research, (iii) National Centre for Zoo Technical Research, (iv) National Centre for Mineral Research & Mining, (v) Malian Cotton Company, (vi) Tropical Agronomy Research Center, are under CNRST.
Currently the National Agricultural Research System is composed of the following institutions:

- *National Agricultural Research Council:* responsible for preparing and supervising the implementation of the national agricultural research policy and strategy.
- The *National Agricultural Research Institute (IER):* responsible for all agricultural research sectors, except rural engineering, mechanization and animal health. The IER operates seven major research programs under its strategic plan. These are:
  - cereals and food legumes;
  - industrial crops;
  - horticulture crops;
  - forestry and fisheries productions;
  - animal production;
  - economics of the commodities;
  - farming systems and the management of natural resources.

The IER also works closely with the Malian Cotton Company, and conducts its applied cotton research on a contractual basis, and the two agencies work together on technology transfer to cotton producers. In addition, IER is a member of various regional networks such as the West and Central African Sorghum Research Network and the West and Central African Millet Research Network (IER, 2000; Lozano, 2002). Twelve of IER's 16 research programs are now executed in collaboration with regional and international partners, which has seriously enhanced the research quality (World Bank, 2002). The nature of these exchanges ranges from on-demand research contracts to exchanges of research results.

1.5.2 Innovation platforms

The large majority of Mali's population depends directly or indirectly on agriculture for their livelihoods. Innovations in this sector could improve the lives of millions of people. The sector faces several challenges that are related to production, post-harvest handling, marketing, policy frameworks and the information/knowledge exchange/flow between the stakeholders. There is a need to increase efforts made towards transforming agriculture in such a way that will reduce poverty, increase food and nutrition security and reduce environmental degradation. To this end, non-governmental organizations (NGOs) and research institutions have initiated and implemented innovation platforms in Mali using the Integrated Agricultural Research for Development approach. Several of the platforms ceased their functioning after the end of the project that put them in place, while others now function as cooperatives.

The different types of innovation platforms implemented in Mali include those based on thematic innovations, platforms specific to a geographical area, and those specific to a sector or value chain. These can be formal or informal, but they do not engage in strategic research or extension initiatives to further develop innovations. Their management is complicated due to the high number of actors with different objectives and expectations. The following table presents functioning platforms in three regions of Mali.

Table 9: functioning platforms in three regions of Mali

Entry Point or Value Chain	Innovations (technical or social and economic innovations)	Location (name and GPS coordinates in UTM or degrees)	Intervention areas (regional/ province/ district/…)	Challenges
Demand for par-boiled rice on the market	Economic	Sikasso	Regional	constant market supply
Constraints relating to processing of fonio grain	Technical	Sikasso	Regional	find good packaging
High cost of potato seed on the market	Technical	Ségou and Koulikoro	Regional	produce important quantities
Supplying quality milk to the city of Koutiala	Technical	Sikasso	Regional	provide milk regularly
Enhancing low land valley production	Economic	Sikasso	Regional	produce important quantities
Enhancing low land valley production	Economic	Sikasso	Regional	produce important quantities
Integrating agriculture into livestock production	Economic	Koulikoro	Regional	Combine the two activities
Integrating agriculture into livestock production	Economic	Koulikoro	Regional	Combine the two activities
Provide certified seeds to commercial enterprises in Mali	Economic	Koulikoro	Regional	To sell more certified seeds
Provide certified seeds to commercial enterprises in Mali	Economic	Sikasso	Regional	meet market demand
Supplying quality rice at national level and with bordering countries	Technical	Ségou	Regional	meet market demand
Supply of good quality product to local and national markets	Technical	Ségou	Regional	meet market demand
Facilitate farmers' access to inputs and land	Technical		National	access to irrigated land and inputs
Supply local and international markets with fat animals	Economic	Sikasso	Regional	meet market demand
Enhance maize production and trade	Technical	Sikasso	National	meet market demand

Source: Authors' compilation

1.5.3 Extension system and organizations

Governmental and parastatal extension services provide most of the agricultural extension and advisory services in Mali. This is due to their high capacity to do so, namely through a number of field officers (841), the large extent of geographic coverage and the broad range of technical areas. A number of NGOs and projects, as well as a few private organizations also provide occasional extension and advisory services (www.worldwide-extension.org/africa/mali/s-mali).

Public Sector

Ministry of Agriculture, Livestock and Fisheries
Key governmental units that provide extension and advisory services related to crop production, livestock production, forestry, fisheries and rural infrastructure development include:

- *Direction Nationale d'Agriculture*
  - Division d'Enseignement Agricole et Aninmation Rurale- has a training staff of ten, based in Bamako, as well as representation at each of the regional "Direction Régionale d'Agriculture" offices. This department works through four *Centre d'Apprentissage Agricole,* based in Dioro, M'Pesoba, Samé, and Samanko. There is a network of "Centres d'Animateur Rurale," or rural community workers' centers in all of Mali's administrative units (the plan is to use these as training centers for young farmers);
  - Division Vulgarisation et Conseil Agricoles, is organized into two sections, research-extension liaison, and extension.
- *Direction Nationale des Productions et des Industries Animales, DNPIA.* The DNPIA has the mandate to develop national policy and programs concerning animal production and industries. The DNPIA is organized into four divisions:
  - Pastoral water management (e.g., development of watering points);
  - Animal product value chains (milk, meat, skins and hides, poultry);
  - Animal industries (e.g., slaughterhouse management; monitoring of livestock markets);
  - Training and documentation.
- *Direction Nationale du Genie Rurale*
- *Direction Nationale des Services Vétérinaires*
- *Direction Nationale des Eaux et Forêts*

Non-Governmental Organizations

Several major NGOs and donor-funded projects provide some extension and advisory services, including:

- Association Malienne pour la Sécurité et la Souveraineté Alimentaires
- Environmental Development Action in the Third World (ENDA) Mali
- Initiatives-Conseils-Developpement
- Institut Polytechnique Rural de Formation et de Recherche Appliquée de Katibougou
- Intercooperation Suisse-Sahel
- Near East Foundation
- Nyeta Conseils

In-Service Training for Extension Staff

- Sasakawa Africa Fund for Extension Education, Programs in Mali: Rural Polytechnic Institute for Training and Applied Research
- Centre d'Apprentissage Agricole, Samanko
- Office de Protection des Végétaux

Public Research Institutions with Extension Unit

- Institut d'Economie Rurale

University-based Extension

Key educational/research institutions with extension training programs or an extension mandate include:

- "Centre d'Apprentissage Agricole, Samanko"
- "Université du Bamako, Institut Polytechnique Rural / Institut Formation et Recherche Appliquée, Katibougou"
- "Institut Polytechnique Rural de Formation et de Recherche Appliquée–IPR-IFRA" Maîtrise en Vulgarisation Agricole/Master in Agricultural Extension

Semi-autonomous Governmental Extension Organizations

Additional key governmental entities and parastatal organizations with geographically or technically limited extension advisory services functions include:

- "Compagnie Malienne pour le Développement des Textiles"
- "Office du Dévéloppment Rural de Sélingué"
- "Office de la Haute Vallée du Niger"
- "Office du Niger"
- "Office Riz Mopti"
- "Office de Protection des Végétaux"
- "Office du Perimetre Irrigue du Baguineda"
- "Office Riz Ségou"

Private Sector Organizations or Firms

Several private sector companies provide some extension and advisory services, including the "Bureau d'Etude et d'Appuis Conseils aux Initiatives Locales/ Sènè Kunda".

Farmer Based Organizations and Cooperatives

Smallholder farmers are organized into producer groups and chambers at the regional level. Each chamber functions as an independent body that represents farmers in the region. All chambers from the nine region form a representative body that serves as the interface between the government and the rural population. The broader role of these groups or associations is to identify farmers' problems, defend their interests, collect and exchange information, and speak on farmers' behalf in improving their welfare. These producer groups include:

- Assemblée Permanente des Chambres d'Agriculture du Mali – Permanent Assembly of Agricultural Chambers;
- Association des Organisations Professionnelles Paysannes;
- Federation of Farmers and Producer Organizations - Coordination Nationale Des Organisations Paysannes Du Mali (www.worldwide-extension.org/africa/mali/s-mali).

1.5.4 Private research and development activities

Most research and development (R&D) activities are implemented by projects, NGOs and parastatals. However, there are some private enterprises which operate in dairy, wheat and vegetables, poultry and livestock. Most of the innovations are thematic such as introduction of new genes, feeds, seeds or soil characteristics.

Examples include:

- *Grands Moulins du Mali (GMM)*: introduce new wheat seeds and conservation practices at farmer level in the north of the country. GMM buys the wheat produced by farmers to supply its' millers in Koulikoro.
- *Grand Distributeur Céréalier du Mali:* produce wheat, rice and potatoes in the "Office du Niger" zone. This enterprise uses thematic innovations from research, such as seeds, irrigation techniques, storage, and conservation at large scale. The rice is milled the enterprise in Ségou.
- *Coopérative Laitière de Bamako:* imports live improved dairy cows from Europe or the United States.
- *Individual poultry farmers:* import chicks from France, vaccines and feeds. They work with veterinarians and researchers to increase their egg production or the weight of broilers.

Most of the privately hired research or extension agents conduct their activities in the field.

1.6 Key challenges, emerging needs and potentials in the agricultural sector

Major constraints to Agricultural Development in Mali

Although Mali has enormous agricultural potential, current low yields and high post-harvest losses limit the net quantity of food available to feed a quickly growing population. Improper feeding practices, high disease burden, poor sanitation and access to clean water and low health service utilization lead to significant health problems, including stunting and wasting. Low household incomes, particularly women, limit peoples' ability to purchase nutritious food. In addition it is difficult for smallholder farmers to obtain credit, as most of the financial institutions see agriculture as a high-risk endeavor due to the dependence of smallholder-based systems on irregular rainfall. The country's weak agricultural policy environment also restricts investment and competitiveness in the sector.

Strategic Solutions to Agricultural Development issues in Mali

The following are strategic solutions that relate to agronomic practices, financial support and capacity building at all levels:

- Increasing yields by encouraging the adoption of improved seeds, fertilizer, and best agricultural production practices, including water management systems;
- Improving post-harvest practices, including storage;
- Expanding access to short- and medium-term credit and improving market information systems;
- Increasing household incomes by boosting production and developing value-added processing, focusing on creating gender equity;
- Increasing access to and the consumption of nutritious foods through value-added processing and by promoting healthy behaviors;
- Improving the government's capacity to collect data, strategically plan, monitor, evaluate, and analyze agricultural programs (USAID, 2010).

1.7 Potential areas for investment in Mali

Based on the general approach presented in chapter 4 of Husmann *et al*. (2015) and in pursuit of efficiency and effectiveness, investment by Germany into the agricultural and food sector are suggested in African countries that:

- Show actual progress in sustainably increasing agricultural productivity through related innovations, as indicated by comprehensive productivity measurement and innovation actions on the ground;
- Have a track record of political commitment to foster sustainable agricultural growth, as indicated by performance under CAADP; and

- Prioritize actions for hunger and malnutrition reduction and show progress, but where agricultural and rural development and nutrition interventions are likely to make a significant difference, as indicated by public policy and civil society actions.

Results of the assessment for Mali[9]:

Expected agricultural growth performance:

- Mali has only achieved an annual agricultural growth rate higher than the 6% CAADP target in four of the years between 2005 and 2014 (www.resakss.org).
- Total agricultural factor productivity in Mali, however, has improved by 10% between 2001 and 2008 (Fuglie and Rada, 2011), indicating a modest innovation record.

Government commitment:

- Mali has a modest track record of political commitment to foster sustainable agricultural growth, as indicated by the government's active participation in the CAADP process and having completed five of the eight steps in the CAADP process (www.resakss.org).
- Likewise, the Mali government has shown a certain willingness to invest in agricultural sector by surpassing the CAADP 10% agricultural expenditure target in six years of the years between 2005 and 2014 (www.resakss.org).
- However, Mali spends only 0.6% of its agricultural GDP on agricultural R&D which is lower than the Sub-Saharan Africa average (www.asti.cgiar.org) and the African Union target value of 1% spent on R&D. This indicates that Mali´s investment into agricultural innovation is not yet sufficient.

Food and nutrition security progress and need:

- Mali has only modestly prioritized lowering hunger and malnutrition, as indicated by the fact that undernourishment in the country has decreased by less than 8%, which is lower than the 10% threshold (FAO, 2014).
- In addition, Mali has a Global Hunger Index (GHI) score value of 13, reflecting a serious level of hunger (von Grebmer *et al.,* 2014)[10]. This indicates the urgent need for investment into the agricultural and food sector in Mali in order to reduce the high level of food insecurity.

Table 10: Mali performance indicators

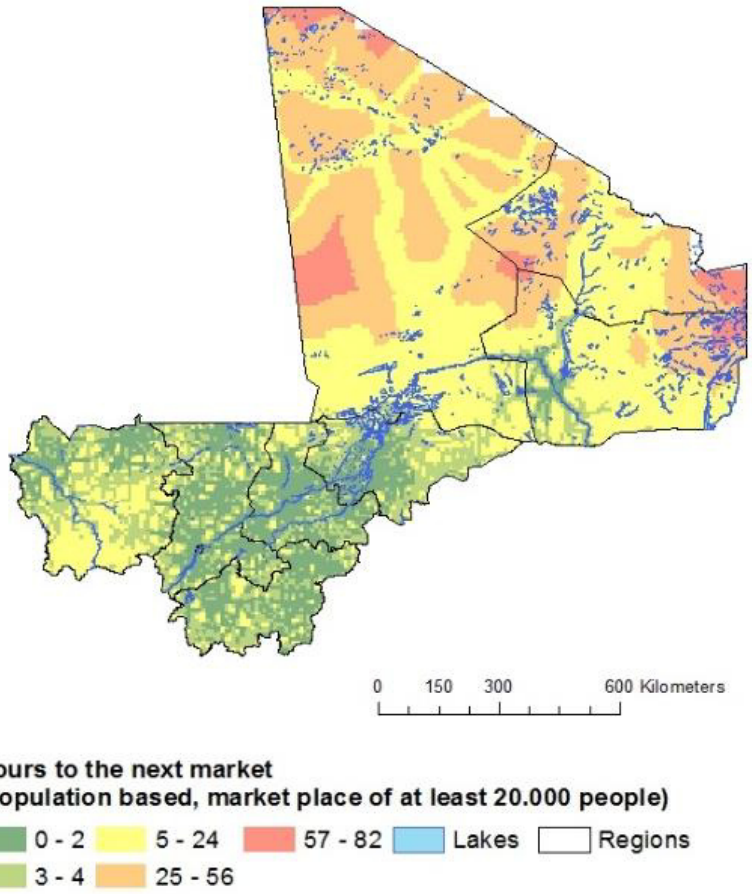
Indicators	Indicator score	Overall score
1. Number of years with more than 6% agricultural growth (2005 to 2014)	4	40
2. Percentage point change in TFP index between 2001 and 2008	10	60
3. Number of years with more than 10% government expenditure (2005 to 2014)	6	60
4. Average share of agricultural GDP spent on R&D (2005 to 2011) in %	0.6	61
5. Steps in CAADP completed	5	63
6. Percentage point improvement in undernourishment between 2001 and 2011	7.6	60
7. Global hunger index (2014)	13	30
Total score (weighted)		52

Data source: Husmann *et al.* (2015)
Note: TFP refers to Total Factor Productivity

[9] Details on the data sources and methodology used in the assessment can be found in Humann et al. (2015)
[10]GHI score values of less than 5.0 reflect low hunger, values from 5.0 to 9.9 reflect "moderate" hunger, values from 10.0 to 19.9 indicate a "serious" level of hunger, values from 20.0 to 29.9 are "alarming," and values of 30.0 or greater are "extremely alarming"(von Grebmer *et al.,* 2014).

The selection of value chains on which to focus is also determined by market access, i.e. transport intensive products should be promoted in areas that are well connected to markets, whereas the remote areas should focus on low volume and livestock value chain segments. Figure 5 presents the average time (number of hours) it takes to reach the nearest market place of at least 20,000 people in Mali.

Figure 5: Distance to markets



Data sources: Hours to next market – Harvest Choice, 2015;
Administrative areas: www.gadm.org, accessed 20.9.2015
Inland water bodies: www.diva-gis.org/gData (water bodies), accessed 20.9.2015

2 Most relevant value chains in Mali

2.1 GIC value chains

2.1.1 Rice

Rice is the dominant commercial food crop in Mali, accounting for 10.6% of agricultural value (see Table 6). This success has been fueled mainly by public-led investments in large-scale, gravity-fed irrigation infrastructure and some positive policy shifts, such as the liberalization of marketing and processing in the main production zone of the Office du Niger during the late 1990s and early 2000s. Malian rice production is competitive and can be profitable, benefiting from higher global prices and

an increase in the demand for local rice. However, despite this underlying competitiveness, there is little private investment flowing to rice production or processing. Rice processing is inefficient, with high proportions of broken rice. Improved mills would add value and increase the size of the market, and this represents a notable investment opportunity, given the proper conditions. The second phase of the Alatona Irrigation Project provides a unique opportunity to develop a public private partnership to invest in large scale rice production. However, the government must take ownership of this commercial vision (Kline and Gordon, 2014).

The opportunities for further development of the value chain include:

- There is high potential for rural poverty reduction by focusing on smallholders and small scale irrigation schemes;
- Income diversification is possible with fish intercropping and horticulture production in the off-season;
- Demand is expected to grow as urbanization continues in Mali and in the region;
- Proposed USAID/Mali investments would complement MCC work in the rice sector by focusing on small-scale irrigation systems.

2.1.2 Irish Potato

Potato production is an old practice in Mali as a whole and in the Sikasso region in particular (1920s). The main traditional basins of production are the regions of Sikasso and Kati. The introduction of potato in the Office du Niger is recent. Today, potato cultivation is integrated into the production systems of farmers in this area because of its high commercial value. Demand is increasing because of the increasing population and changing eating habits both at the national and the sub-regional levels. Yields vary from 20 to 40 t/ha, depending on the variety and the cultivation techniques used by the farmer in the cold season. The estimated average yield is 23 t/ha. The average annual production is about 50,000 tons, of which 80% is produced in Sikasso. The sector is structured in three levels: seed importers (all based in Sikasso, seeds mainly come from Europe), producers, and buyer traders. Potato growers have never received the type of formal training that cotton producers have received. The production techniques are mostly traditional: manual plowing of land, irrigation with gourds from small wells, and storage in bulk in huts. Most head farmers belong to a farmers' organization. The various farmers' organizations are Village Associations and the association of potato producers in Sikasso. In addition, producers work closely with government extension services, various NGOs and microfinance institutions. Over 56% of producers are in contact with state services, 35.7% with private organizations, and only 7.1% with financial systems. There are several constraints related to the commercialization of potato in Mali, mainly the lack of storage and conservation facilities (warehouses), the lack of more efficient irrigation techniques, the oversupply of the produce, due to short selling periods and perishability, the lack of processing and transformation, funding, and the lack of policies and structuring of the value chain (Diakité and Zida, 2003; Banque Nationale de Développement Agricole, n.d.).

2.1.3 Vegetables

Mali produces ample amount of vegetables, mainly in the inland valley. However, the value chains for these vegetable crops are poorly developed, and this results in low returns to the different stakeholders along the value nodes. Vegetable production only represents 1% of total harvested area and 2.8% of production volume (see Table 6).

The input supply is poorly organized in Mali; the recommended inputs are substituted by cotton inputs, which are inappropriate and dangerous for human health and the environment. The supply of improved seeds is low, the certified seed sector for vegetables is very limited, resulting in controlled varieties being used heterogeneously or not at all. The seeds of vegetable crops are difficult to obtain,

and when they are available, they are very costly for producers. Other constraints are the high costs of transport, post-harvest losses and poor conservation of fresh vegetables.

2.1.4 Fruit (Mango)

The mango value chain is the next most important exportable commodity in Mali, after cotton. With cotton stagnating as the country's main export, the government of Mali is promoting the cultivation of other agricultural produce as a means of overcoming poverty in one of the poorest countries in Africa. The mango value chain is largely underdeveloped in Mali. It is limited to a few local actors. The value chain, however, needs to be optimized, from the smallholders' cooperatives, the fruit-pickers and local intermediaries to the international buyers and the consumer. Mango production makes up 0.5% and 0.3% of total production volume and value in Mali, respectively (see Table 6).

2.2 Other relevant value chains

The other relevant value chains besides those selected for the GICs are discussed in this subsection. The relevance in this case is based on, among other things, the extensive review of the literature available on the crop, the importance of the crop in relation to share of area cultivated (harvested), production volume, and trade importance (import and export).

Some value chains identified by the European Union mission in Mali, the National Agricultural Priority Investment Program (PNIP-SA), and USAID include maize, small ruminants, poultry, millet/sorghum, cashew nuts, shea nuts and sesame. Some of the value chains are relevant because of their importance in household food systems (millet/sorghum, maize) and others for their income generation potential (small ruminants, poultry, shea nuts, cashew nuts and sesame). Other value chains of interest are dairy and meat.

2.2.1 Maize

Maize is one of the crops identified as a high-potential cereal by the Government of Mali, due to its high yields and the growing demand at the country and sub-regional levels. In fact, Mali is one of the largest producers of maize in West Africa with an annual production of over 1.7 million metric tons and an average yield of more than 2.1 t/ha in 2014 (FAOSTAT, 2016). In 2009/2010, the Government of Mali adopted and launched a program for the Intensification of Maize production. Through this program, government subsidies for maize reached 2.286 billion CFA francs for that crop year, all of which supported the provision of fertilizers to farmers. This program adopted under the Malian government Rice Initiative also benefited the national cotton program, given the widely practiced three-year crop rotation technique of cotton with cereals in the cotton production zone (Nhliziyo, 2015; Abate et al., 2015). Nonetheless, climatic conditions (droughts), high prices of improved seeds, rudimentary farming techniques and inefficient conservation methods (open air exposure of maize leading to aflatoxin contamination and quality losses) are major constraints that undermine the crop's value chain (Nhliziyo, 2015).

2.2.2 Millet and sorghum

Millet and sorghum together are among the most widely produced and consumed cereals in Mali, particularly in rural areas and low-income households. Millet and sorghum are the top two crops produced in terms of area harvested (29.5% and 19.8% respectively), and among the top four for production volume (14.6% and 10.4% respectively) (see Table 6). They both play a crucial role in food security in the country. However, production and yield growth have remained low compared to other crops such as rice and maize. Millet and sorghum are farmed mainly for subsistence. Their low commercial value (see Table 6) creates a disincentive for investment and wide commercialization

efforts. Other constraints in the sector include the limited availability of improved seeds, financing, conservation facilities, and the lack of policies to promote growth of the sector (USAID EAT, 2012a).

2.2.3 Cotton

Cotton is the most important export good and accounts for more almost 80% of export volume and nearly 90% of export value (see Table 8). One of the major policies to promote production was the input subsidy measures undertook by the Malian government in 2009 after increasing world energy and input prices. As one of the top producers in Africa, Mali plans to produce 800 000 tons of raw cotton per year by 2018. Production during the 2014/15 season reached over 550 000 tons compared with 440 000 tons in the previous season. The Malian government increased input subsidies and also lowered the price of fertilizer. Some 3.5 million farmers are involved in the growing of cotton in the country (Nhliziyo, 2015; Bennett and Rawle, 2015).

2.2.4 Cashew nuts

Cashew production in Mali occurs around the Sikasso region, along the Côte d'Ivoire and southern Burkina borders, and in the Koulikoro region. In 2014, the country produced slightly more than 72,000 tons of cashew nuts (FAOSTAT, 2017). The crop is harvested between February and April and its drought-tolerant nature can help in reducing soil erosion. The production of cashew involves around 12,000 small-sized farms and most of the production is exported to India (Bass, 2013).

2.2.5 Livestock

Livestock plays an important role in agriculture and trade in Mali and in other semi-arid West African countries in general. It accounts for almost 30% of the country's GDP, and 85% of rural and peri-urban households in Mali raise various ruminants. The animals are essentially fed on rangelands, fodder crops or cotton seed cake (USAID EAT, 2012b).

2.3 Promising agricultural products and value chains

In addition to assessing the returns on investments into institutional innovations in Ghana, analyses are also undertaken in order to choose the most promising value chains in the country. This analysis is important because it provides an objective indicator for priority value chains that would have the highest returns on investments into technological and institutional innovations. The trio objectives of PARI (to promote and support the scaling of proven innovations in the agri-food sector; to support and enhance investments in the GICs through research; and to contribute to the development of the agri-food sector in Africa and India through the identification, assessment and up-scaling of innovations) guide the selection of indicators. The indicators should thus focus on improving the food and nutrition security, reducing poverty and improving the market participation of the small holder farmers. Taking into account the availability of data and the purpose of the study, four indicators that focus on poverty and market potential are used to select the five most promising agricultural products from the long list of agricultural products that the country produces and sells. These indicators are:

1. Trade potential (Revealed Comparative Advantage (RCA) index): computed to identify value chains over which the country has revealed, albeit may not necessarily potential, comparative advantage in the export market. The revealed comparative advantage is an index used in international economics for calculating the relative advantage or disadvantage of a certain country in the production and export of a certain class of goods or services as evidenced by trade flows. It is based on the Ricardian comparative advantage concept. We use Balassa's measure of RCA to determine the competitiveness of selected agricultural products in overseas export markets. In the present case, the RCA index compares the share of a given agricultural product in the country's export basket with that of the same product in total world exports

2. Yield gap: used to assess the expected return of the envisaged investment on the given country value chains. The yield gap of a crop grown in a certain location and cropping system is defined as the difference between the yield under optimum management and the average yield achieved by farmers. A standard protocol for assessing yield potential and yield gaps is applied for some crops based on best available data, robust crop simulation models. It is a powerful method to reveal and understand the biophysical opportunities to meet the projected increase in demand for agricultural products.
3. Average yield growth: used to examine the potential of the product for poverty reduction. The most widely used indicator of crop productivity is production per unit of land (also referred to as crop yield). Average yield growth may reduce poverty in the following ways: (1) higher yield implies higher surplus product that could be sold in the market and thereby increase farmers income, (2) higher surplus product mean large quantity of food supplied to urban and rural market at a relatively lower price which in turn reduces urban and rural food poverty, (3) higher agricultural productivity will stimulate growth in the non-agricultural sector through its strong backward and forward linkage. For example, it boosts growth in the industry sector by freeing agricultural labor and reducing urban wage pressure (Lewis, 1962), and (4) agriculture's fundamental role in stimulating and sustaining economic transition, as countries (and poor people's livelihoods) shift away from being primarily agricultural towards a broader base of manufacturing and services (DFID, 2004).
4. Total production of the crop as a share of total supply (production + imports) is also used to assess the relevance of investing on that crop .Because it signals whether the agro-ecological system is suitable for the production of that crop in meeting the global demand for that particular crop. The ratio of production to total supply also illuminates the degree of integration of the producers that particular crop, small holder farmers in most African countries cases, into markets. The extent to which small holder farmers are able to participate in both input and output markets, and the functionality of those markets, are key determinants of their willingness and ability to increase marketable surpluses (Arias, 2013). Across the developing world, smallholders farm in diverse agro-climatic systems which together with their assets and skills, shape their economic lives. Markets and the extent to which they are functioning well, also play a determining role.

Note: The share of production of that particular crop over the total crop production is another key indicator considered in this study while assessing the relevance of investing on a particular crop in a country. This indicator is used as an eliminating criteria. If the share of a given crop out of total crop production is less than 0.5 %, we consider it as less relevant and exclude from the list of most promising value chains.

The summary of the five most promising value chains based on the RCA index, average yield growth and relevance of crop is reported in Table 11 below. The production share, RCA index, actual yield growth and relative yield gap for the GIC value chain(s) are also reported at the bottom of the table, when they are not included in the list of the first five most promising value chains.

Table 11: Selection of the most promising agricultural product /value chain

	Rank by RCA		Rank by Yield progress***		Rank by yield gap		Rank by relevance of crop	
Rank	**Name of agricultural product**	**RCA index (2011)**	**Name of the crop**	**Average annual yield growth (2005 to 2012)**	**Name of staple crop (rain fed)**	**Relative yield gap (%)****	**Name of agricultural product**	**Production share of supply (2011)***
1	Animals live	108	Maize	21	Maize	87	Sorghum products	114
2	Sesame seed	54	Rice, paddy	12	Rice	73	Maize products	102
3	Goats	32	Cow peas, dry	12	Sorghum	89	Millet products	101
4	Oil, groundnut	30	Sweet potatoes	8	Millet	84	Cassava products	100
5	Cotton lint	30	Yams	6			Sweet potatoes	100
	Fruit, fresh	0.06	Vegetables, fresh	4			Vegetables	99
	Vegetables	0.05	potatoes	1			Potatoes	93
	potato	0.01					Rice	81

Source: * Own computation based on FAO 2015 data, ** from Van Bussel *et al.* (2015)
Note: ***a minimum of 0.5% production (volume) share threshold is used as a screening (crop relevance) criteria.

Results of assessment (Table 11):

- The trade potential (RCA index) is very high for live animals, sesame seed, goats, groundnut oil, and cotton lint. This indicates that Mali has a comparative advantage (in the export) of these commodities. The RCA value for all the GIC selected crops – fruit, vegetables and potato – is much lower than 1, indicating that Mali has a comparative disadvantage in the export of the GIC selected crops;
- The yield performance indicating progress suggests that over the CAADP period (2005 to 2012) maize, rice (the GIC selected value chain), cow peas, sweet potatoes, and yams are the five most promising crops. The other GIC selected crops, vegetables and potatoes, show a positive although small growth performance over the CAADP period;
    - Yield gaps indicate potential from another angle, and are observed to be high for rain-fed maize, rice, sorghum, and millet, indicating the high potential return of investing in these value chains.
    - In terms of relevance (production share of supply), the leading value chains are sorghum, maize, millet, cassava and sweet potatoes. The total production of the first three value chains exceeds the total demand. The supply of most of the GIC selected value chains are also fully produced in the country.

2.4 Summary on selection of agricultural products and value chains

This chapter (chapter 2) has presented different relevant and important value chains in Mali based on different criteria – resulting on different value chains. In summary, the three top value chains – GIC selected value chains, other relevant value chains, and those identified by analysis of promising agricultural products and value chains – are presented in Table 12. The summary table shows that only the GIC-selected value chain of rice is identified as promising in terms of yield progress and yield gap by the analysis of promising agricultural products and value chains. However, a number of overlaps in the value chains is shown between the analysis of promising agricultural products and the review of literature. These products/value chains are maize, millet, sorghum, and livestock.

Table 12: Summary of all value chains

GIC value chains	Other value chains	Promising agricultural products and value chains (top 3) RCA	Yield progress	Yield gap	Relevance of crop
Rice	Maize	Animals live	Maize	Maize	Sorghum products
Irish potato	Millet & sorghum	Sesame seed	Rice, paddy	Rice	Maize products
Vegetables	Cotton	Goats	Cow peas, dry	Sorghum	Millet products
Fruit (mango)	Cashew nuts				
	Livestock				

Source: Authors' compilation

3 Innovations in value chains in the past 20 years

3.1 Main limiting factors

All value chains in Mali have common characteristics which limit their development. These are:

- Irregularities of supply due to dependence on climatic conditions;
- High variability in the quality of products;
- Scattered production by a large number of smallholders;
- Limited number of traders;
- Degraded roads and long distances between producers and consumers;
- Limited collective actions by actors due to weaknesses in cooperative organizations (collective purchase or selling).

In their study of a rice-potato farming region in Sikasso, Ebi *et al.* identified several factors that present both challenges and areas of improvement, affecting smallholders in Mali. They stressed crop diversification and variety improvement; soil and water conservation through integrated natural resource management; access to credit for fertilizer, equipment and storage; communication outreach; and weather forecast as crucial to helping farmers mitigate the effect of climatic conditions and to improve their yields for crops such as rice, maize, potato, etc. Furthermore, the seed sector should be better organized, and the issue of land tenure needs to be addressed (Ebi *et al*., 2011).
Value chains can also be improved by integrating smallholders into. Vertical integration along the value chains is made difficult by the lack of efficient smallholder farmers' associations or groupings, the inconsistency of the quantity and quality of supply, coupled with limited knowledge dissemination and skill training. Hence, there is a large need for capacity building at all levels of the chain (Nedelcovych and Shiferaw, 2012).

3.2 The most important / beneficial innovations in the relevant value chains of Mali

In this section, we describe some of the key innovations that have been initiated in selected value chains in Mali in the last 20 years. The innovations described are considered significant or beneficial because of their widespread adoption, proven positive impact on increasing productivity, potential to increase incomes and generate employment, potential to be adapted to environmental challenges (such as drought), employment etc.

3.2.1 GIC value chain

Innovation in terms of improved rice productivity, quality and cost-effectiveness: Improving productivity involves developing and distributing effective, productive and disease-resistant varieties of rice and introducing technology to support these varieties (crop systems: pricking out, preparation of the soil, fertility management, fight against disease and pests, etc.) (Zoundi *et al.,* 2005).

Innovation in terms of creating opportunities to capitalize on local rice: Relevant innovations can be generated from research into ways to process or add value to broken rice. Africa Rice has carried out a range of initiatives to use broken rice, traditionally considered worthless, as a type of flour for pastries (cakes, croissants, pancakes, etc.) to partially or totally replace wheat flour. "Estimates show that the development of appropriate processing technologies can upgrade broken rice with a commercial value of 50- 60 CFA francs per kg to a more competitive product (50% rice flour and 50% wheat flour) for use in pastries" (Zoundi *et al.*, 2005, p. 38). These technologies will allow their users to save almost 125 CFA francs per kg; the rice-wheat flour mixture would cost around 275 CFA francs per kg as opposed to 400 CFA francs per kg for pure wheat flour. In addition, "100% transformed rice products also have the advantage of being gluten-free (certain consumers being gluten-intolerant)." (Ibid).

Innovation in terms of setting up a "Crédit stockage villageois": This represents a warranty scheme that provides credit to rice farmers, allowing them to store the crop for several month after harvest in order for them to take advantage of rising market prices. The implemented scheme proved to be very popular with women, with many more wanting to join (Ebi *et al.*, 2011).

3.2.2 Other value chains and cross-cutting innovations

A groundbreaking soil conservation technique called ridge tillage was developed in Mali in the 1990s by the Malian Agricultural Research for Development Center and the USAID Soil Management Collaborative Research Support Program. The technique, which consists of drawing permanent ridges on the fields, reduces soil erosion and substantially increases rain water infiltration. Application of this technique in Southern Mali resulted in the increased growth of crops as well as indigenous and perennial tree in the farmed landscapes (Shea tree, etc.). Traoré *et al* (2004) found that ridge tillage increased water infiltration by 10% of total annual rainfall (800 mm) and cereal yields (millet, sorghum and maize) by an average of 30%, and of over 50% during dry years. Ridge tillage also contributed to raising the water table and increasing ligneous bio-mass and carbon sequestration.

The McKnight foundation, as well as several other national institutes, such as the IER, supported research programs and strategies to enhance nutrition through the biofortification of food and crops, using local diversity. The Mcknight foundation specifically took interest in how to increase iron and zinc bioavailability in sorghum and pearl millet (Birner *et al.*, 2007). The International Sorghum and Millet Collaborative Research Support Program (INTSORMIL CRSP), funded by USAID, was also a scientific collaboration between international and local stakeholders to contribute to food security in Mali. The project worked on seed multiplication, on-farm testing, and exchange of varieties of sorghum and millet, with the goal of identifying and disseminating the best cultivars and combining them with fertilizer and other best practices. Their work also included storage, disease and pest controls, as well as tests for drought-resistant varieties, adaptation, stability, and acceptability through multi-environment experiments. The project brought together multi-disciplinary food and animal scientists, extension educators, from Burkina Faso, Mali, Niger, Nigeria, and Senegal, and volunteer organizations, private industries, and universities in the United States (INTSORMIL, 2011). The project, through its incubation centers, targeted the entire value chains of sorghum/millet. It provided training to trainers and farmers, improved seeds, cultivars, fertilizers and integrated resource management techniques. Further activities included building storehouses, and transferring technology and equipment to local entrepreneurs, to food and feed processors, to brewers, to bakeries, and to women groupings. This technology would enable them to transform and integrate the cereals in their production of sorghum flour, couscous, biscuits, boulettes, poridges, local desserts (degue), poultry feed, etc. Students from

local universities also benefited from related long term training in the United States. The project ended in 2013, but there is potential in further replicating and upscaling its successful elements to the whole country (INTSORMIL, 2012).

Furthermore, innovations developed for similar value chains in other countries can prove beneficial and applicable in Mali. A breeding program was implemented at the International Trypanotolerance Centre in The Gambia in the 1990s in order to improve the trypan-tolerant Djallonké sheep and the West African Dwarf goat for low-input management systems. The purpose of the program was to increase milk and meat output per head, while retaining resistance to diseases. The program took a participatory approach by involving farmers in defining the breeding goals, while providing technical assistance to participating farmers (Kosgey *et al.*, 2006). This program was inexpensive, needing basic infrastructure and logistics. Considering its success, and the similar population of ruminants in Mali, implementing a similar program there is worth considering.

Besides research, initiatives such as cereal banks (Crédit Stockage Villageois for rice), and the World Bank's Agricultural Competitiveness and Diversification Project (in collaboration with the Malian government) provide technical and financial assistance to farmers and agribusinesses to help boost performance in key agricultural value chains, such as cereals, livestock, etc.

4 Suggestions for collaboration

The German collaboration for scaling agricultural innovation will necessarily need to align with existing initiatives in the country that address pertinent issues that the productivity of the agricultural sector. Nutrient depletion and degradation of soils, forests and water, as a result of overgrazing and the pressures of a growing population, are all issues that continue to pose serious challenges to medium- and long-term food security in the country. In addition, low and erratic rainfall has reduced production levels and increased the vulnerability of rural population to food insecurity (IFAD, 2008). New approaches and technologies are urgently needed to be introduced into agricultural development strategies in light of climate change and resource degradation. Sustainable management of land and water resources is of crucial importance for the future.

Other potential cross-cutting innovations in the value chains would be related to packaging, storage, producers' organization and improving production. These areas are presently least covered by innovations.

The existing agricultural research and innovation structure in Mali constitutes the entry point for effective partnership. The partnership should consider the IER with its 16 research programs and their specific research focus. Governmental institutions like the Ministry of Livestock and Fisheries, CNRST and the Ministry of Secondary and Higher Education and Scientific Research should also be considered as important potential partners for collaboration. Such partnerships would provide technical and political support, thus increasing the effectiveness of any joint venture.

Implementation research could be carried out in collaboration with national and international institutions on the different value chains. Research could focus on the following:

- Market analysis of the different value chains by compiling a comprehensive profile of the products, and their associated industries and markets;
- Identification of key policies, regulatory and institutional that constrain the performance of the value chains and proposition of appropriate solutions;

Specific focus areas could be:

- Analysis of the impact of new vertically-integrated operators in the rice value chain to identify costs and benefits;
- Analysis of the Irish potatoes seed supply chain;
- Increasing the competitiveness of mangoes from Mali on national and international markets.

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Annex A: Background Information on Nutrition

This annex provides background information on diet quantity and quality, child feeding practices and nutrition status (including micronutrient deficiencies) and definitions of the food and nutrition security indicators presented in Chapter 1.4.2.

Background on food and nutrition security

Diet quantity: Dietary energy supply per capita is an indicator of diet quantity that can be gauged against a population's average dietary energy requirement. The data are based on FAO's food balance sheets that estimate the quantity of each food item available for human consumption at the national level. It has to be emphasized that supply does not equal intake: Supply includes food that households feed to domestic animals or pets and food that they waste. Also, a sufficient average supply of dietary energy (or a nutrient such as protein) may leave those parts of the population deprived that have greater-than-average requirements or lower-than-average intakes. Indicators of undernourishment and food over-acquisition seek to consider the distribution of dietary energy consumption in the population and the minimum/maximum requirements of the average individual in a country (Cafiero, 2014).

Diet quality: Assessing diet quality requires a look at the composition of the diet. In the absence of national food consumption surveys for most countries, data from FAO's food balance sheets are used. The percentage of dietary energy supply from starchy staples (cereals, roots and tubers) is a rough indicator of diet quality: generally, the higher this percentage, the lower the micronutrient density of the diet; starchy staples are rich in carbohydrate and good sources of dietary energy, but they are usually not very micronutrient-rich. Non-staple foods are important for micronutrient and protein supply: Foods of animal origin are good sources of high-quality protein and vitamin A as well as highly bioavailable iron and zinc (meat, fish) and calcium (milk, small fish eaten whole with bones). Pulses and nuts are also good sources of protein and micronutrients. Fruits and vegetables provide a range of micronutrients while generally contributing little dietary energy (USDA, 2016).

The shares of dietary energy supply from carbohydrate, protein, and fat roughly indicate whether the diet is balanced in terms of its macronutrient composition. The recommended shares of dietary energy are 55-75% for carbohydrate, 10-15% for protein, and 15-30% for fat (WHO, 2003). It should be noted that these shares do not reveal whether dietary energy supply per capita and average protein supply are insufficient, sufficient, or excessive in absolute terms. A diet that meets the average dietary energy requirement for Africa as a whole (2200 kcal/day according to FAO, 2016) and provides 55-82.5 g protein per day and 36-73 g fat per day contains the recommended shares of 10-15% of dietary energy from protein and 15-30% of dietary energy from fat. For an adult weighing 60 kg, a protein intake of 50 g/day is considered sufficient, and 60 g/day for an adult weighing 75 kg. No safe upper limit of protein intake has been established, but it is unlikely that intakes of twice the recommended level pose any risk (WHO/FAO/UNU, 2007).

Child feeding practices: Feeding practices are determined by local food availability and household access to food, but also by maternal knowledge and care. Breastfed and non-breastfed children aged 6-23 months should eat foods rich in iron (meat, fish, or eggs) and fruits and vegetables rich in vitamin A daily, and consume at least 4 out of 7 food groups every day (PAHO/WHO, 2003; WHO, 2005; WHO, 2010).

Nutrition status: Household food security, the health environment, and mothers' caring capacity influence children's dietary intakes and the risk of infection, and thereby their nutrition and health status (UNICEF, 2013). Wasting, or acute undernutrition, is the result of recent rapid weight loss or the failure to gain weight that is caused by inadequate diets or infection. Stunting is the failure to grow adequately and results from chronic or recurrent undernutrition or infection (UNICEF/WHO/World Bank, 2016). Stunting in early childhood can have irreversible consequences, such as impaired motor and cognitive development, shorter adult height, lower attained schooling, and reduced adult income, whereas wasting carries a higher mortality risk (Victora et al. 2008; Black et al. 2013; Olofin et al. 2013). Overweight in children and overweight and obesity in adults occur when dietary energy intakes exceed

dietary energy requirements. Overweight and obesity increase the risk of noncommunicable diseases (UNICEF/WHO/World Bank, 2016).

Micronutrient deficiencies arise from insufficient intakes or absorption of essential vitamins and minerals. Major causes are poor diets, diseases, and increased requirements during life stages such as early childhood, pregnancy, and lactation. Micronutrient deficiencies are not limited to poor populations with inadequate dietary energy intakes, but may coexist with overweight and obesity in individuals and communities. Measuring micronutrient deficiencies poses challenges: There is often a need to resort to proxy indicators and large data gaps persist. Anemia, for example, is used as a proxy indicator for iron deficiency, although only about half of the global burden of anemia can be attributed to iron deficiency. Iron deficiency anemia impairs cognitive and motor development, causes fatigue and low productivity, and may result in low birth weight and increased maternal and perinatal mortality if pregnant women are affected (WHO 2015b). Whenever survey data on anemia prevalence are not available, modeled estimates from WHO (2015b) are used. Vitamin A deficiency increases the risk of vision problems, infectious diseases, and death among children (Imdad et al., 2010). Without exception, the data on vitamin A deficiency that are presented in this dossier are modeled estimates (Stevens et al., 2015, quoted in IFPRI, 2015).[11]

Table A1: Cutoffs to identify nutrition problems of public health significance in children

Category of public health significance	Stunting	Wasting	Overweight	Iron deficiency anemia
Severe	≥40	≥15	≥10	≥40
Moderate	30-39	10-14	5-9	20-39
Mild	20-29	5-9	3-4	5-19

Source: Adapted from World Bank (2006) and based on data from WHO (1995) and WHO (2000)

Notes: The cutoffs for public health significance were applied to prevalence rates of stunting, wasting, overweight and iron deficiency anemia (estimated from anemia prevalence) that were rounded to the first decimal. In the tables in Chapter 1.4.2, the data have been rounded to integers, which may lead to seeming contradictions: In a region where 29.8% of children under five were stunted (30% if rounded), stunting would be considered a mild public health problem, and in a region where 30.3% of children under five were stunted (also 30% if rounded), stunting would be considered a moderate public health problem.

Indicator definitions

Dietary energy supply: National average energy supply, expressed in kcal/caput/day (FAO, 2016).

Average dietary energy supply adequacy: Dietary energy supply expressed as a percentage of the average dietary energy requirement. Each country's average supply of calories for food consumption is divided by the average dietary energy requirement estimated for its population to provide an index of adequacy of the food supply in terms of calories (FAO, 2016).

Prevalence of undernourishment: Probability that a randomly selected individual from the population consumes an amount of calories that is insufficient to cover her/his energy requirement for an active and healthy life (FAO, 2016). This indicator seeks to estimate of the percentage of individuals in the population who are chronically undernourished because they fail to meet their minimum dietary energy requirements on a consistent basis.

Prevalence of food over-acquisition: Percentage of individuals in a population who tend, on a regular basis, to acquire food in excess of their maximum dietary energy requirements (FAO, 2016). **Dietary energy supply from cereals, roots and tubers:** Percentage of dietary energy supply provided by cereals, roots and tubers (FAO, 2016). A higher share of dietary energy supply from cereals, roots and tubers is generally associated with a lower micronutrient density of the diet.

[11] Iodine deficiency disorders are an important public health problem in many countries. They are not discussed here because salt iodization, the main prevention and control strategy, is not related to agricultural value chains.

Dietary energy supply from carbohydrate: Percentage of dietary energy supply provided by carbohydrates, calculated by subtracting dietary energy supply from protein and dietary energy supply from fat from 100%.

Dietary energy supply from protein: Percentage of dietary energy supply provided by protein, calculated as average protein supply times 4 kcal/g divided by total dietary energy supply.

Dietary energy supply from fat: Percentage of dietary energy supply provided by fat, calculated as average fat supply times 9 kcal/g divided by total dietary energy supply.

Average protein/fat supply: National average protein/fat supply, expressed in g/caput/day (FAO, 2016).

Minimum dietary diversity: consumption of 4+ food groups: Percentage of children aged 6-23 months fed four or more food groups in the 24 hours preceding the survey. The food groups are 1) infant formula, milk other than breast milk, cheese or yogurt or other milk products; 2) foods made from grains, roots, and tubers, including porridge and fortified baby food from grains; 3) vitamin A-rich fruits and vegetables (and red palm oil); 4) other fruits and vegetables; 5) eggs; 6) meat, poultry, fish, and shellfish (and organ meats); 7) legumes and nuts (ICF International, 2015, The DHS Program STATcompiler).

Consumption of foods rich in vitamin A: Percentage of children aged 6-23 months who consumed foods rich in vitamin A in the 24 hours preceding the survey. Foods rich in vitamin A include meat (and organ meat), fish, poultry, eggs, pumpkin, red or yellow yams or squash, carrots, red sweet potatoes, dark green leafy vegetables (for example, cassava leaves, pumpkin leaves, kale or spinach), mango, papaya, and other locally grown fruits and vegetables that are rich in vitamin A (ICF International, 2015, The DHS Program STATcompiler).

Consumption of foods rich in iron: Percentage of children aged 6-23 months who consumed foods rich in iron in the 24 hours preceding the survey. Foods rich in iron include meat (and organ meat), fish, poultry, and eggs (ICF International, 2015, The DHS Program STATcompiler).

Child wasting: Percentage of children under five who are wasted, that is, have weight-for-height below minus 2 standard deviations of the median of the WHO Child Growth Standards. This means that they are too thin for their height (UNICEF/WHO/World Bank, 2016).

Child stunting: Percentage of children under five who are stunted, that is, have height-for-age below minus 2 standard deviations of the median of the WHO Child Growth Standards. This means that they are too short for their age (UNICEF/WHO/World Bank, 2016).

Child overweight: Percentage of children under five who are overweight, that is, have weight-for-height above 2 standard deviations of the median of the WHO Child Growth Standards. This means that they are too heavy for their height (UNICEF/WHO/World Bank, 2016).

Adult overweight and obesity/overweight and obesity among women of reproductive age: Percentage of adults aged 18 years or older/percentage of women of reproductive aged 15-49 years whose body mass index (BMI) is equal to or greater than 25 kg/m2 (WHO, 2015a; ICF International, 2015, The DHS Program STATcompiler). BMI is calculated by dividing body weight in kg by squared height in m.

Adult obesity/obesity among women of reproductive age: Percentage of adults aged 18 years or older/percentage of women aged 15-49 years whose body mass index (BMI) is equal to or greater than 30 kg/m^2 (WHO, 2015a; ICF International, 2015, The DHS Program STATcompiler).

Adult underweight/underweight among women of reproductive age: Percentage of adults aged 18 years or older/percentage of women aged 15-49 years whose body mass index (BMI) is below 18.5 kg/m^2 (ICF International, 2015, The DHS Program STATcompiler).

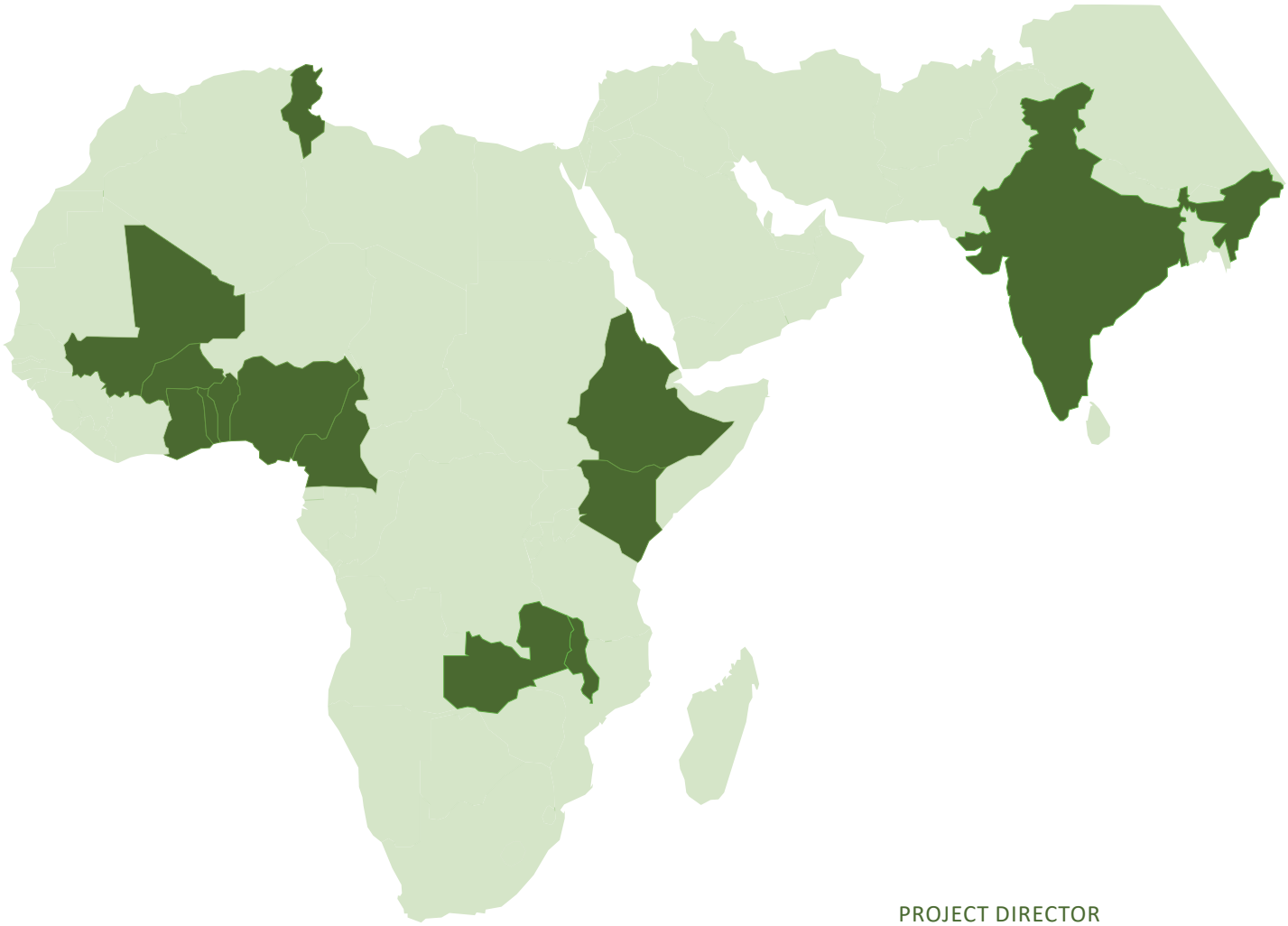
Vitamin A deficiency: Percentage of children aged 6-59 months with a serum retinol concentration below 0.7 µmol/l.

Anemia in children: Percentage of children aged 6-59 months with anemia, namely, a blood hemoglobin concentration below 11.0 g/dl.

Anemia in women: Percentage of women aged 15-49 years with anemia, namely, a blood hemoglobin concentration below 12.0 g/dl for non-pregnant women and below 11.0 g/dl for pregnant women.

ABOUT PARI

The Program of Accompanying Research for Agricultural Innovation (PARI) brings together partners from Africa, India and Germany to contribute to sustainable agricultural growth and food and nutrition security in Africa and India as part of the “One World, No Hunger” Initiative supported by the German government.



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