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Projecting Benin's food gap for 2025 with BenIMPACT

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Introduction

According to the Human Development Index (HDI) Benin is ranked among the least developed countries in the world by the World Health Organisation (WHO). With an annual growth rate of 2.8 percent, Benin's population of 6.8 million people today will double within 26 years, and the low per capita income level of 430 € p.a. improves only slowly due to this high population growth. Even though the overall nutritional status seems to be satisfactory, particularly children and woman in poor families are threatened by protein malnutrition and insufficient energy intake. Food shortages sporadically occur before the harvesting season when stocks are running low.
Agriculture plays an important role in Benin's economy as the most important source of income (about 65 percent of the workforce are engaged in agriculture according to UNDP, 2003), and domestic markets are sensitive to world market trends of agricultural prices, especially those of cotton and rice. However, growth in productivity is generally low, which triggers questions about the future food supply situation if population numbers keep growing at current rates. In this paper, both an insufficient food energy intake per capita as well as the need to import calories is used as indicators for a future food gap.
The questions at hand are analysed using the farm household model BenIMPACT (Benin Integrated Modeling System for Policy Analysis, Climate and Technology Change), which has been developed as part of an interdisciplinary research effort carried out by the IMPETUS-Project ("Integrated Approach to the Efficient Management of Scarce Water Resources in West Africa") during the last two years. A major goal of IMPETUS is to deliver reliable scenarios on water-related developments in Benin until 2025 under special consideration of climate change. As agricultural production is an important part of the hydrological cycle, farm modelling is an indispensable tool to analyse the impact of climate change on land use and food security. The results presented in this article are aimed at giving an idea about the range within which a possible food gap might develop in Benin over the next two decades. Two alternative scenarios regarding a possible food gap in Benin are suggested for the year 2025.

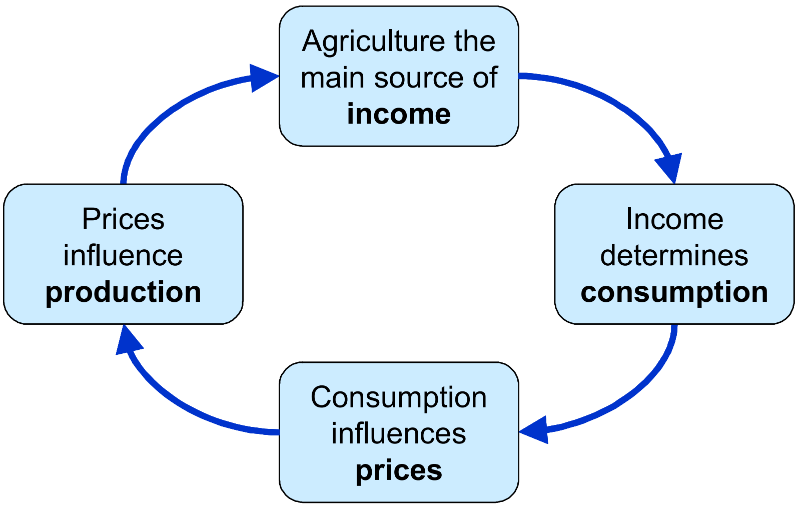
The BenIMPACT Model

Overview

The development of the food situation is analysed here with the assistance of BenIMPACT, a regionalised Agricultural Household Model (AHM) for Benin. Most AHMs are designed for village level analysis or a unique household, sometimes even considering the single individuals in the household. The main characteristic feature of an agricultural household model is that production and consumption decisions are made simultaneously, for instance by assuming that one person is responsible for both areas (BARDHAN, 1999).

In the paper at hand a variety of this model class is applied to the complete country, partitioned into the twelve departments of Benin. Additionally, the neighbouring countries of Benin as well as the rest of the world are represented with stylised supply and demand functions. Even though the model captures the whole country, decision-making in agricultural production is oriented at the farm household model, where production influences income, which in turn determines consumption, as figure 1 illustrates.

Figure. 1: Decision processes in BenIMPACT



Twelve representative agricultural households at the departmental level have been constructed on the basis of national and regional statistics as well as own data collection of production costs, each representing the production, consumption and trade of all farm households in the department. Each a separate supply and demand module are solved iteratively assuming that first production is decided upon, and then consumer utility is maximized subject to the budget constraint resulting from the income stemming from production.
Eight major important food and cash crops are currently included in the model.[1] The integration of a livestock module is in progress, so results do not yet comprise these commodities. But as animal products contribute only around 4 percent to the energy content of the average Beninese diet (FAO, 2003), errors in food supply for energy caused by the lack of animal products is marginal at present.
Each year is divided into four periods in order to capture the differences between rainy and dry season as well as multiple harvests per year for some crops. Storage of food is possible, and income can be generated from storage (inter-temporal arbitrage) as well as from trade (spatial arbitrage).

[1] These are maize, cassava, yam, pulses, cotton, sorghum and millet, peanuts, and rice.

Supply model

The supply module in BenIMPACT is a quadratic programming model designed in the fashion of positive mathematical programming (PMP). The objective function to be maximised consists of revenues from production minus costs plus a quadratic term (see eq. 1 below). Costs consist of trade costs, storage costs and input use in cropping. The inclusion of explicit trade and storage costs implies that regional and seasonal prices differ by fixed price spans provided that trade takes place. For regions in Benin, net supply is defined in equation 2, with fixed coefficients.

Equation 3 represents the market balance. For each product in each period and each region, the fixed demand quantity H is balanced by production, trade, storage, and by processing consumption in the case of cotton. The dual value λ (shadow price) of the market balance is used as the regional and seasonal price in the demand module. Production is constrained by the availability of land (eq. 4), which is, however, not binding in the reference period. Instead, production is limited by the upward sloping marginal cost curve. Equation 5 is limiting processing consumption of cotton to factory capacities.

$$\begin{aligned} \max & \sum_{jot} \left(T_{j'row'ot} - T_{'row'jot} \right) P_{'row'ot} + \sum_{jot} F_{jot} P^{r}_{jot} \\ & - \sum_{jot} S_{jot} SC_{jo} - \sum_{jkot} T_{jkot} TC_{jkot} - \sum_{dit} N_{dit} P_{dit} \\ & - \sum_{du} X_{du} \left(A_{du} + \tfrac{1}{2} \sum_{v} B_{duv} X_{dv} \right) - \sum_{not} N_{not} \left(a_{not} + \tfrac{1}{2} b_{not} N_{not} \right) \end{aligned} \qquad (1)$$

subject to

$$N_{dgt} = \sum_{dv} X_{dv} IO_{dvgt} \qquad (2)$$

$$N_{jot} + \sum_{k} T_{kjot} - \sum_{k} T_{jkot} + S_{jot-1} - S_{jot} - F_{jot} \geq H_{jot} \qquad \lfloor \lambda_{jot} \rfloor \quad (3)$$

$$\sum_{ju} X_{ju} l_{jut} \leq L_{jut} \qquad (4)$$

$$\sum_{t} F_{jot} \leq K_{jo} \qquad \lfloor \pi_{jo} \rfloor \quad (5)$$

where

j,k	= all regions except rest of world 'row'
$d \subset j$	= domestic regions
$n \subset j$	= neighbour countries
g	= goods in the model
$o \subset g$	= outputs
$i \subset g$	= inputs
u,v,w	= production activities
t	= time periods 1 to 4
T	= transport flows
TC	= transport cost
P	= prices of goods
P^r	= regulated price at Factory
F	= processing consumption
S	= storage
SC	= storage cost
N	= net sales of farm
X	= activity levels
l	= land use of activity in periods
L	= land availability
K	= maximum factory capacity (only for cotton)
A	= linear parameter of cost function for domestic regions
B	= quadratic parameter of cost function for domestic regions
a	= linear parameter of cost function for neighbour countries
b	= quadratic parameter of cost function for neighbour countries

Two important inputs, fertiliser and labour, are not yet modelled, but remain a challenge for future developments of BenIMPACT.

Demand model

In order to determine household consumption, the dual values of the market balances are taken as the new consumer prices. The prices together with production, trade, storage and input costs are used to compute household income. Income and prices enter the demand model, which determines human consumption for the next iteration with the supply model[2].
The demand system is a Generalised Leontief expenditure system (DIEWERT and WALES, 1987) with time separability. The latter means that products consumed in different time periods are considered different goods with no cross price effects except over income. The system is calibrated at base year demand and prices to represent demand elasticities derived from the FAO world model as closely as possible.

Data for the base year and trends towards 2025

The model is calibrated in order to replicate the average of the years 2001 and 2002 (called 'base year' further on), while scenarios are calculated for 2025, as the Beninese national economic planning horizon lasts until this year. For the base year, production is computed using statistics from national agricultural organisations such as the annual reports of the Ministry for Agriculture or ONASA, disaggregated to time periods using a crop production calendar together with precipitation data. Demand is computed from data on regional per capita consumption of food crops, seasonally adjusted using observed variations in prices and the elasticities entering the demand system calibration. Trade and storage costs are estimated by minimising deviations from an assumed trade cost function and of prices from observed prices, respecting the market balance and arbitrage conditions (JANSSON 2005).
The assumptions for the scenario 2025 are based on trends in population growth, internal migration and national income per capita. Demographic projections for Benin's departments for 2025 are provided by DOEVENSPECK (2004). It is assumed that the neighbouring countries will face the same development as Benin, meaning that excess supply of these countries remains unchanged. Moreover, real world market prices are kept constant. An annual growth in income for the non – agricultural sector of one percent per capita is assumed. As for the trend in land availability, the marginal cost curve for increasing land is shifted to the right as population increases, such that if there were no constraints on land expansion or migration, the population increase would be responded to by increased land use.

Comparison of two Scenarios for 2025

Two alternative scenario runs are presented in the following: the first scenario is considering all the trends on demography, income and crop productivity mentioned in the previous chapter. However, it may well happen that the projection on income growth may be too optimistic. Taking into account that many countries in Sub-Saharan Africa have experienced hardly any real per capita income growth during commodity or political crises in recent decades, a cautious exploration of the possible future developments has also to take less optimistic growth expectations into account. This is also relevant for Benin, as the country's arable land resources are becoming more and more scarce and degraded. While repeated shortfalls in domestic supply

[2] In order for the system to converge also when the supply elasticity exceeds the demand elasticity, the demand system contains linear supply equations that are calibrated to the supply model result of the last iteration, and a price expectation mechanism that adjusts the expected price before the next supply iteration.

might easily be balanced by food imports financed by the non-agricultural sectors under continuing economic growth, a future ‘growth shortfall’ might indeed lead to a real food gap. Thus, the second scenario is assuming zero per capita income growth.

Tables 1 and 2 show selected results for the two scenarios for 2025 compared to the base period 2001/02. The simulation results for 2025 show a strong increase in production for both scenarios, even stronger as population growth. Net trade of food crops, however, develops differently: in the scenario with income growth, sorghum and yams are the most important exported food crops which are traded to neighbouring countries. Imports of rice and particularly maize, however, increase most as a result of improved incomes generated predominantly in non-agricultural activities. Table 2 shows that the average nutritional status of the population improves under the growth assumption from 2381 to 2408 kCal per capita and day, which is somewhat lower than the estimations of IFPRI (2005) for all Sub-Saharan Africa in the business as usual scenario. Protein intake from crops as calculated by BenIMPACT rises by about 4 % without considering a possible increase in the consumption of animal products. According to these estimations, the food gap does not seem to become wider until 2025. However, as a differentiation between household types is not yet part of the model (e.g. rural-urban), it is difficult to judge upon possible consequences of unequal income distribution. If the poor population strata will be able to participate in the positive development, the continuation of current trends allows an optimistic view on Benin’s food situation. Additional calorie intake is delivered by roots and tubers (cassava and yams) in the first place, followed by pulses.

Table 1: Production, net trade and consumption of important food crops in Benin, 2001/02 and 2025 (in thousand MT)

	Base period 2001/02			*Scenario 2025 with 1% growth*			*Scenario 2025 with zero growth*		
	Gross production	*Net trade*	*Human consumption*	*Gross production*	*Net trade*	*Human consumption*	*Gross production*	*Net trade*	*Human consumption*
Cassava	1777	0.0	1056	3386	20.5	1991	3342	28.9	1947
Maize	654	-2.1	384	1137	-70.5	736	1140	-46.5	705
Pulses	106	-0.5	74	201	-6.1	145	200	3.3	134
Sorgh., Millet	218	0.0	175	446	30.2	327	447	34.3	323
Yams	1788	0.0	913	3455	27.4	1737	3417	34.0	1711
Peanuts	95	-0.6	85	184	10.2	154	184	11.9	152
Rice	41	-157.6	176	83	-277.2	316	83	-260.2	300

But what happens if economic growth in the non-agricultural sectors will not be sufficient to provide additional per capita incomes? Comparing the two simulations for 2025 the first with an increase in non agricultural income and the second without this increase, one can notice that gross production of agricultural products is nearly unchanged. Nevertheless, the outcome is less reassuring with respect to the resulting energy supplies from food.

As prices of traditional staple foods (cassava, yams) decrease due to lower demand resulting from lower incomes, domestic production of staples is lower than in the growth scenario. At the same time, lower prices of cassava and yams improve the competitiveness of these crops internationally, thus increasing net exports. Net imports of maize and rice are lower than in the growth scenario due to less available income of consumers. Consequently, the consumption of calories from cereals per capita decreases by almost 3 %, while the calorie intake from roots and tubers remain nearly constant compared to 2001/02.

Table 2: Population and calorie intake from important food crops in Benin, 2001/02 and 2025

	Base period 2001/02	*Scenario 2025 with 1% growth*	*Change to base year in %*	*Scenario 2025 with zero growth*	*Change to base year in %*
Population in 1000	6769	12594	86.0	12594	86.0
Calorie intake[a]	2381	2408	1.1	2337	-2.0
of which					
Roots and tubers	1048	1066	1.7	1045	-0.2
Cereals	1042	1051	0.8	1012	-2.9
Pulses	102	108	5.5	100	-2.5
Peanuts	189	184	-2.7	181	-4.3
Calories produced domestically[a]	2300	2328		2275	
Calorie net trade[a]	-81	-80		-62	
in % of total calorie intake	3.4	3.3		2.7	

a. kCal/capita and day

In the base year scenario and the growth scenario the dependence of Benin on trade to ensure a sufficient energy supply to its growing population remains nearly the same. Net imports of food energy decrease to 3.3 % of total available energy while the supply situation improves. In the scenario without growth in income, fewer calories are imported with the consequence that the available amount of food energy is decreasing. Net imports of food energy decrease further, but accompanied by a worsening supply situation. It has to be kept in mind that both the domestic production of food energy as well as the capacity to import food decrease in the no-growth scenario. To fill the shortfall in energy production compared to the growth scenario, 71 kCal per capita and day would have to be imported in addition. This food gap would then amount to 2.9 % of food energy intake. In order to reach the Sub-Saharan average food energy consumption level of 2526 Kcal per capita and day in 2025 projected by IFPRI (2005), the food gap would even amount to 7.5 % of the desired energy intake.

Conclusions

The results on the food prospects in Benin represent work in progress. Several caveats apply to the figures calculated with the help of the BenIMPACT model. First, no distinction between different income groups was made, which makes it difficult to give recommendations on targeting alleviation measures. Another area where the model requires improvement is the production module, where restrictions to use additional land are rather flexible, and thus not sufficiently taking into account regional land scarcity, degradation of land, and repercussions of economic growth (and the possible lack thereof) on the availability of credit to buy fertiliser and pesticides. In order to get better projections of protein supply, animal products must be included into the simulations. Finally, the implementation of a labour market is a challenge for the next model version.

Nevertheless, the simulation show that Benin as a whole can improve its food supply situation, but only if either current growth continues, or if current population growth rates decrease. On the other hand, the no-growth scenario indicates a slight worsening of the food supply situation, but not an outright catastrophe. After all, Benin is still in a much favourable situation regarding its national food security than its northern land-locked neighbours in the Sahel. As a continued expansion of the agricultural area to satisfy increased future demand may come to its limits, both improving productivity and trading with the neighbouring countries and with the rest of the world will be necessary. But this again requires an ongoing growth of the non-agricultural economy so that people can afford buying food.

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