

Seasonal water demand in Benin's agriculture

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Abstract

This paper describes and analyzes agricultural water demands for Benin, West Africa. Official statistical data regarding water quantities as well as knowledge on factors influencing the demand for water are extremely rare and often reveal national trends without considering regional or local differences. Thus policy makers usually work with this estimated and aggregated data, which make it very difficult to adequately address regional and local development goals. In the framework of an interdisciplinary analysis the following paper provides insight into water quantification and detects water problems under seasonal aspects for agriculture according to regional differences. Following the definition of the Food and Agriculture Organization [FAO, 1995. Water Report 7. Irrigation in Africa in Figures. Rome] agriculture is divided into irrigation and livestock watering, which were analyzed using different field methods.

The study reveals that although water supply in absolute terms seems to be sufficient in Benin, seasonal water problems occur both in irrigation and in livestock management. Thus arising seasonal water problems are not the consequence of general water scarcity but more linked to three major problems. These problems emerge from difficulties in technical equipment and financial means of farmers, from the specific local conditions influencing the access to water sources and the extraction of groundwater, and third from the overall low organizational structure of water management.

Therefore regional differences as well as a general improvement of knowledge on better management structures, technical know how, and access to credits for farmers need to be considered in national strategies in order to improve the agricultural water usage in Benin.

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1. Introduction

“Water is essential for life, and an adequate supply is prerequisite for human and economic development” (WCED, 1987). Even today, issues regarding water have not lost importance in the scientific community, as seen from international water conferences or millennium goals. In Benin, one of the poorest countries in the world (human development index: position 159 of 175 countries), research has proved that water shortages in households exist. The reasons of shortages are located less in water availability than in water access, depending on seasonality, as well as in financial and technical problems

(Behle and Schopp, 2003). This poses the question as to whether seasonal water shortages also apply to Benin's agriculture because in general, the agricultural sector is the largest water consumer.

In most countries more than 70% of water is withdrawn by agriculture (FAO, 2007). However, knowledge about the hydrological cycle, water availability, and water use are incomplete in many countries. A lot of statements are based on estimates from international organizations and do not accurately reflect present conditions in detail. In this context, the aim of this study during the period of the IMPETUS project, financed by BMBF¹ and MSWF² is to investigate water

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demand in the agricultural sector of Benin. Furthermore, a concept of supply management has to be developed for more efficient water use and coordination of water policies.

With a surface area of 112,630 km² Benin is a small country in West Africa. Climatic conditions vary from south to north and can be divided into three climate zones:

1. Sub-equatorial climate from the coastline to Savé in the Centre of Benin with two rainy seasons (April–July and October–November),
2. Sudan climate with one rainy season consisting of the South-Sudan climate from Savé to Bembereke (semi-humid tropical climate) and the North-Sudan climate from Bembereke to Malanville (dry tropical climate),
3. Climate of the Atacora range in the North West of Benin with one rainy season from April to October.

It happens that the onset of the rainy season varies compared to the annual average of several years. Moreover, rainfall quantities differ each year. These two variables lead to uncertain conditions for agricultural production and regional supply scarcities (Preuss, 1994; Mama, 1998). Since the beginning of the 1960s a trend of declining average annual rainfalls could be measured in the entire West African Region.

Although several studies rank Benin as a country without severe water scarcity (Falkenmark, 1989; Engelmann et al., 2000), this average number neither reveals seasonal differences nor regional differences within the country. Especially in the dry season, the temporal water availability causes a lot of supply problems for the population. For more than 84% of the population, water is not sufficiently available to cover all needs at the household level. This paper will show that this can be partly transferred to the agricultural sector where insufficient water supplies under specific circumstances occur. Water shortages in agriculture impact a large population group. Indeed, about 65% of the population works in agriculture and is a major economic issue mostly because of the subsistence economy. The intensity of labor comes along with low productivity per person which can be seen in the actual agricultural share of GDP of 32.2% (World Bank, 2006)

Agricultural production is characterized by rainfed agriculture for subsistence. Common crops are cereals, maize and sorghum, legumes, beans and peanuts and the tubers, yams and manioc. In general, 70–80% of the export value is produced by Benin's agricultural sector (BMZ, 2004). The main export good is cotton, followed by cashew and palm oil. This demonstrates the high dependence of the economy on a few export products.

Livestock management is characterized by extensive production methods based on resources like natural pasture and water, and on crop residues or house garbage. Productive livestock, such as cattle, sheep, goats, pigs, and poultry is kept for multi-purpose use such as income, consumption, draught power, manure, capital formation (cattle for long-term and small ruminants rather for short term capital formation), religious festivities, and ceremonies. Since the main production takes place in the North and urban agglomerations are located in the South, transport of livestock occurs from north to south.

Therefore, water demand in Benin's agriculture is composed of water demand for rainfed cropping, irrigation and for water requirements of productive livestock. While in crop production precipitation quantities are required in certain periods, water for livestock keeping is required throughout the year in order to assure production. These continuous water requirements combined with accessibility to watering locations often cause difficulties in the countries south of the Sahara during the dry season. Many of these problems are aggravated due to the different ethnic affiliations of farmers and animal keepers.

2. Methods and definitions

Two different surveys were conducted in order to investigate water consumption in the agricultural sector of Benin considering the following definition of the FAO (1995):

Agricultural water withdrawal is the annual quantity of water withdrawn for agricultural purposes. It includes irrigation and livestock watering.

Water consumption by irrigation and livestock watering is regarded separately in this paper. Due to the existing diversity in available data and the given conditions in these sub sectors, different field methods and analyses were necessary.

2.1. Irrigation

Irrigation is defined as:

Water artificially applied to soil and confined in time and space. It enables to meet the water requirements of a crop at a given time of its vegetative cycle or to bring the soil to the desired moisture level outside the vegetative cycle. The irrigation of a field includes one or more watering per season.

The irrigation systems can be fully equipped, just partially equipped, or managed in a "traditional" way. The equipment may be for permanent or supplementary irrigation (FAO Glossary, 2006).

The irrigation infrastructure of Benin consists of three different levels: urban and periurban irrigation with watering cans mainly for vegetable cultivation near big cities, small-scale irrigation in inland valleys ("bas-fonds") with simple irrigation techniques, and large-scale irrigation systems for the production of rice, sugar cane and palm oil.

The selection of single investigation area within the three levels was made by local experts of the irrigation sector (Faculté des Sciences Agronomiques (FSA), Genie Rural, Centre Régionaux de Promotion Agricole (CeRPA), etc.). Due to the limited number of large-scale irrigation systems in Benin all systems could be investigated. Urban and periurban irrigation systems of vegetables are mostly located in the south of Benin due to high population density (Mbaye and Remson, 1997). The experts chose four southern cities with the highest amount of irrigation systems. A list of all farmers using this

kind of irrigation did not exist and also secondary data on irrigation (size of irrigated plots, location, water sources, etc.) in the four cities were not available from local authorities. It was a non-probability sampling because farmers not being on their fields during the interview time had a zero probability to be included in the sample. Those farmers working on their fields were randomly selected and interviewed. Due to time and money constraints, 125 farmers were interviewed and finally 100 questionnaires could be used for the analysis. In every city equally 25 farmers were included in the analysis. Due to missing data the actual share of irrigation in all farm activities in the different cities was not known and this did not allow for a proportional sampling. The results should therefore not be generalized from the survey sample to a broader population. SPSS 12 was used for data analysis.

The selected irrigation systems in the inland valleys represent different stages of irrigation intensity and user organization. They were chosen as case studies for different possible irrigation appliances in order to provide insight in this irrigation level. Table 1 shows the investigation areas and the applied field methods in each level. All methods aimed to identify the current situation within the irrigation sector and the influence of problems concerning availability of water and land, application of pesticides, demand and commercialization. Moreover, future trends and the development of the sector until the year 2025 were anticipated.

The quantitative analysis of the irrigation water withdrawal was carried out in urban and periurban irrigation systems with calculations based on indications made by the interviewed farmers in the questionnaires.

With the help of participatory observations, and a method of empirical social research, the gathered information was confirmed and completed. To get a view of the trend in irrigation at the national level, interviews with seven experts from the national authority “Genie Rural”, part of the Ministry for Agriculture, were carried out.

Fig. 1 shows an overview of the different research areas for irrigation and livestock surveys.

2.2. Livestock

For the livestock sector, two formalized surveys were conducted. In the first survey 75 local animal keepers were interviewed while for the second, 34 local experts were consulted. Animal keepers were interviewed in particular, for aspects concerning water resources and natural forage in detail. The survey was realized in three main investigation areas: Ouidah

(South), Tchaourou (Central Benin) and Gogounou (North) due to great differences in land availability and production systems (see Fig. 1). In the South, Ouidah stands for the periurban production system near the urban agglomerations Cotonou, Abomey and Porto-Novo. The research side of Tchaourou, in Central Benin, represents a region where large areas are still available for pasturing but where conflicts regularly occur over resources between farmers and livestock keepers. The third region, Gogounou in the North, has less precipitation compared to the other two regions and is known for their strict organization and innovation in marketing. In order to see the differences in location and transport connection to the local or rather interregional street net, 25 animal keepers in four to five different villages in every main investigation area were selected. The choice of the final sample of 75 selected animal keepers was made by local producer organizations due to the general suspicion of animal keepers to national officials or strangers.

The expert survey was carried out as a complete inventory count. Finally 34 of the 37 experts, who were evaluated in a previous field survey, participated. All of them are engaged in livestock management at the University of Abomey, the Direction de l’Elevage, the CeRPA, the national farms or Development and private organizations. Some of the questions corresponded directly to the other survey to get an impression whether both opinions match. In order to get better assessment of the results, a workshop was carried out at the end of the field research. All experts who participated in the survey were invited to discuss the results and the future development of livestock in Benin. Both livestock surveys were evaluated with the program system SPSS 12.0.

3. Results

The two parts of agricultural water requirements – irrigation and livestock – are analyzed particularly on used water sources, calculated water requirements as well as the most urgent problems and limiting factors.

3.1. Seasonal water sources for irrigation and livestock

Irrigation plays a minor role in Benin’s agricultural production. According to an investigation conducted in 2005 only 7131 ha or 0.23% of the agricultural area is irrigated. This is 2% of the irrigation potential estimated by the FAO (2005) of 322,000 ha.

Table 1
Field methods in the investigation areas

Irrigation level	Sample size	Investigation area	Specific field method
Urban and periurban irrigation	Micro-approach $n = 100$	Grand Popo, Ouidah, Cotonou, Porto-Novo	Standardized questionnaires
Irrigation in inland valleys	Micro-approach $n = 5$	Batran, Komigüea, Bagou, Kokiboru, Odo-Otchère	Interviews with user groups
Large-scale irrigation systems	Complete inventory count $n = 6$	Malanville, Koussin-Lélé, Dévé, Savé, Pobé	Interviews with local experts

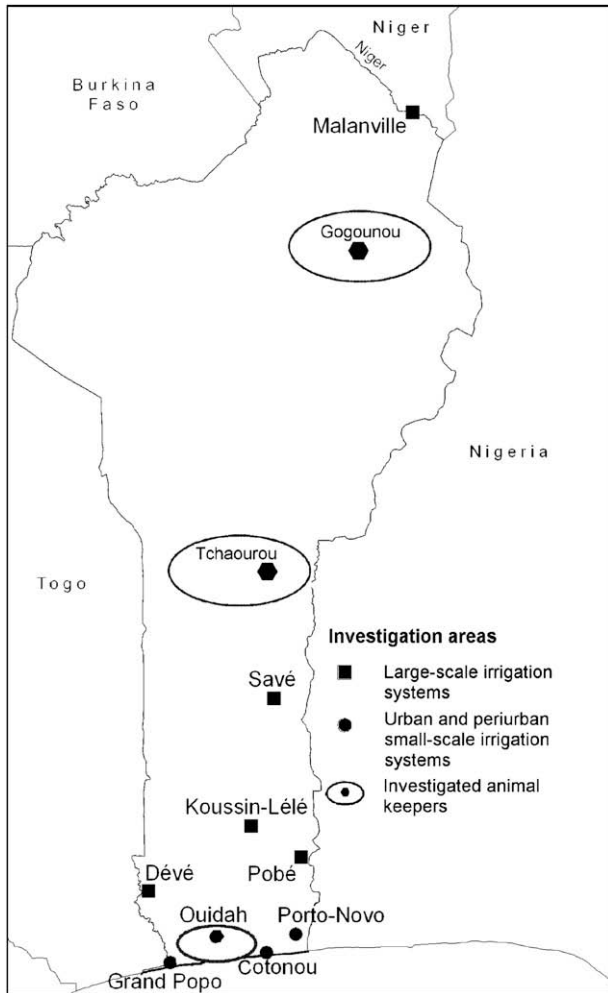


Fig. 1. Research areas of the irrigation and livestock survey.

The irrigation methods used in Benin are divided into three types of irrigation (see Section 2): large-scale irrigation systems using surface irrigation are located in Malanville, Dédé and Koussin-Lélé in order to produce paddy rice. In Malanville and Koussin-Lélé rice can be harvested two times per year, while rice in Dédé is only produced once a year during the rainy season (April–July). These three irrigation systems were installed as a part of a program of technical cooperation between the Republic of China and Benin during the 1960s. Managed by local teams of Chinese irrigation experts, many well organized and highly productive irrigation systems were developed. But after the departure of the Chinese, the integration of the local people in organization and management processes failed. This caused the degeneration of all the irrigation systems in the 1970s. The three existing irrigation systems were rebuilt again with support of Chinese irrigation experts. Currently, a team of two or three Chinese experts take on responsibilities for technical guidance and maintenance.

The cultivation of vegetables like lettuce, tomatoes and pimento takes place near the big cities for supplying the urban population. Irrigation is based on simple irrigation techniques like irrigation with cans and rarely with motor pumps. Only 15% of the interrogated farmers indicated to be organized in

Table 2

Estimated potential surface (in ha) and the area under cultivation (in ha) in inland valleys

Department	Estimated potential area (ha)	Area under cultivation ^a (ha)	Number of known inland valleys
Atacora/Donga	45,400	500	191
Alibori/Borgou	33,000	260	162
Collines/Zou	65,000	405	247
Mono/Couffo	17,400	105	79
Platéau/Ouémé	19,000	30	116
Atlantique	15,000	n/a	119
Total	194,800	1300	914

Source: NEPAD/FAO, 2005.

^a Irrigated and non-irrigated.

cooperatives with collective acquisition of inputs, and some have regulations for water allocation between the farmers (Hounsou 2006, personal communication).

The inland valleys, mainly spread over the Centre and North of Benin, are not traditionally used for agricultural production. Because of seasonal flooding during the rainy season the area has not been adapted for the production of traditional food crops like maize, yams and millet. But the conditions are suitable for production of wetland rice. Currently, only 1300 ha, which is nearly 0.7% of the potential of agricultural production in inland valleys are realized despite financial support and technical aid by the FAO and the Beninese government³ (Table 2, and for the departments see Fig. 4).

The large-scale irrigation systems were built in areas where large amounts of surface water exist. Irrigation systems like Savé and Pobé have water reservoirs in case of water shortages brought on by low river levels.

The system of water sources used in irrigated inland valleys is more complex, because different sources are used together. On the slopes, small dwells retain rainwater, whereas the bottom of the valley is watered by run-off and ascending groundwater, and often completed by the flooding of smaller rivers. This complex hydrogeological system hampers constant and secure agricultural production (Windmeijer and Andriessse, 1993).

In urban and periurban irrigation systems water sources depend on applied irrigation techniques (motor pumps/watering cans). The main water source concerning motor pump irrigation is groundwater from boreholes (72%), from wells (13%) and from swamplands (“marigots”, 15%). In watering can irrigation, the water sources are quite different (72% from swamplands, 20% from wells, 6% from waterholes and only 2% from boreholes). During the dry season, water scarcity constitutes a problem for 45.3% of the interviewed farmers. There is a significant correlation with water scarcity depending on water access between the water source “groundwater from boreholes” and other water sources (chi-square after Pearson has a *p*-value smaller than 0.000). This result seems reasonable because of the high amount of groundwater, the

³ 1986–1994 projet “Inventaire, Etude et Aménagement de bas-fonds” (BEN/84/012; BEN/91/002).

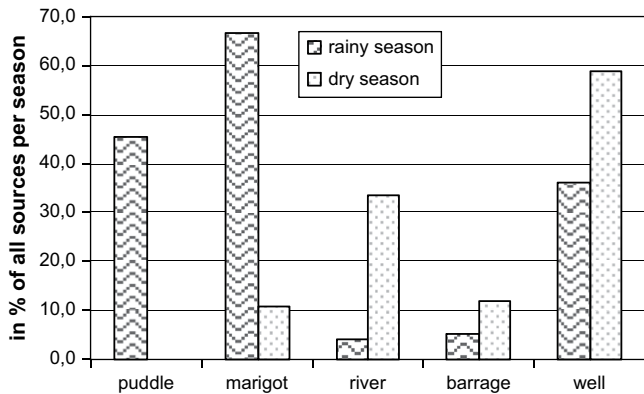


Fig. 2. Water sources depending on season.

Fig. 1. Puddles and marigots are the main water sources during the rainy season, whereas rivers and wells become more important during the dry season (Fig. 2).

A more differentiated view, according to sources depending on season and region, is given in Fig. 3. Wells have an exceptional position in the southern investigation area where they are used year-round because they are nearly the only source of water. Here, no significant difference in the use of water sources depending on seasons can be identified. However, in the northern and central regions, there is a high significance in seasonal differences (a *p*-value smaller than 0.001). For the northern and central regions the corrected coefficients of contingency between the season and water source show a medium contingency of 0.57 or rather 0.51. In the North, wells do exist but they are used only in the dry season. A special feature of the central region is large rivers which are water-bearing even during the dry season. But during the rainy season puddles and marigots dominate the supply as those sources are closer to villages and camps.

Barrages, which are often the focus of developmental aid for livestock management, did not show great importance in any of the regions. It seems that either none of these regions are in an area of barrages or other water sources are preferred.

Not explicitly mentioned in the survey is the water content of feedstuffs which reduces the absolute required water quantity. Water content in plants is high if humidity is high, and livestock keepers turn to these sources during the rainy season. Additionally, small rivers are water-bearing during rainy season, and allow animal keepers to travel short distances to water sources in order to avoid damage to cultivations. In the northern and central regions, all interviewed animal keepers accompany their livestock to water sources and wait until watering is finished. In the dry season, some additional water comes from wells. The minimal and maximal distances to water sources are illustrated in Fig. 4.

The minimal and maximal distances differ among the three regions and are statistically not homogenous (the chi-square after Pearson has a *p*-value smaller than 0.001). The animal keepers in the central region have to travel with their livestock the farthest. Due to a 100% supply of wells on the farms, animals are tended on farms in the South. In the North, more

low groundwater level in the area near the coastline (1–5 m), and the high groundwater recharge rate.

Productive livestock (cattle, sheep, goats, pigs and poultry) are not evenly distributed across Benin because of the existence of different adaptations according to natural landscapes and cultural backgrounds. Cattle are kept predominately in the north of the country while pigs are mainly kept in the south. For all livestock it can be said that extensive production methods are applied based on natural resources. Different strategies to deal with seasonal shortages of input factors have been developed. One obvious strategy dealing with scarcity is transhumance, the seasonal migration of livestock following the supply of both forage and water.

As livestock requires water year-round, in contrast to cropping, several different water sources are used. To assure adequate water supplies, natural rivers and waters, seasonal waters like marigots and puddles as well as storage reservoir, and wells and trucks are employed as water sources for livestock. Natural waterways and waters are traditional and predominant watering places for cattle, whereas small ruminants mostly have to find the needed water themselves around the house. During the dry season, puddles, some marigots, and many small stream courses dry up and other water sources are required. Different water sources, according to the season, are needed, and this fact is reinforced by the survey shown in

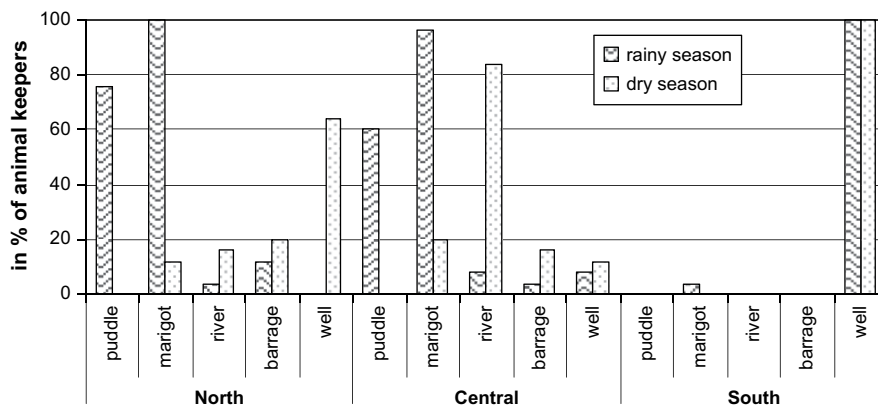


Fig. 3. Water sources depending on seasons and regions.

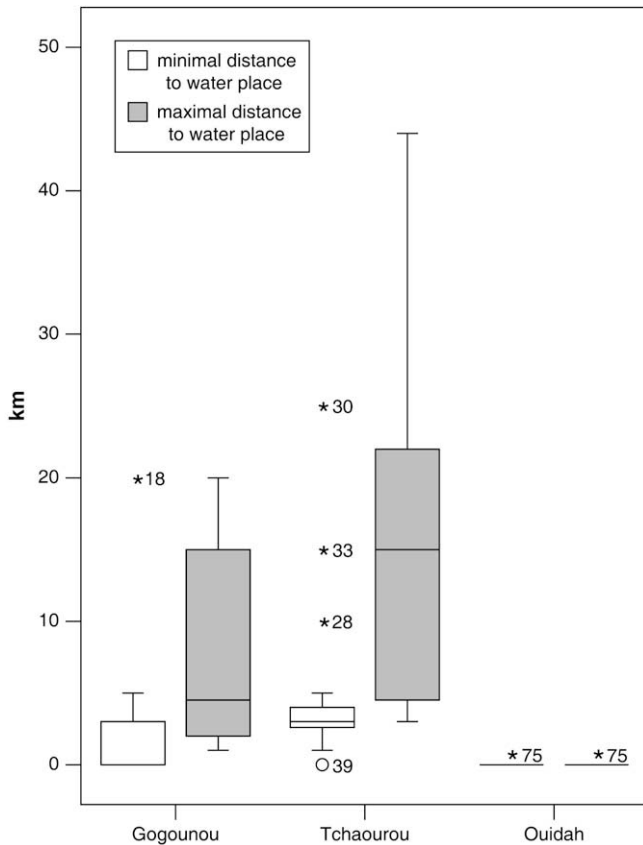


Fig. 4. Distance to water sources.

wells exist than in the central region, so the minimal and maximal distances are shorter than in the central region. These various distances among the three regions indicate differences in the watering infrastructure and suggest differences in water availability.

3.2. Quantification of water requirements

As described above, water consumption for irrigation purposes has been calculated at two different levels summarized in Tables 3a and 3b.

In general, the amount of water used for irrigation fluctuates due to different soil conditions, water household of the soil, exposure (sunny/shadow), kind of crop, period of crop cycle and crop density. Factors like distance to water sources, size of irrigated area, availability of working time may also influence water withdrawal.

In Fig. 5 the minimum and maximum data values for the survey of farmers in urban and periurban irrigation systems depending on the irrigation technique (irrigation with motor pump/irrigation with watering can) are represented. The box contains the middle 50% of the data. One can see that the

Table 3a
Water withdrawal in m³ in different levels of irrigation

Level of irrigation	Investigation area	ha	Water withdrawal (m ³)
Large-scale irrigation systems	Malanville, Savé, Pobé, Devé, Koussin-Lélé	5531	9,280,159
Urban and periurban irrigation systems	Porto-Novo, Cotonou, Ouidah, Grand Popo	1600	151,533,400

size of the box and the distance between minimum and maximum data values:

- are larger in the dry season compared to the rainy season in both irrigation systems,
- are larger in cases of irrigation systems that use motor pumps in both seasons.

As expected, water withdrawal varies between dry and rainy seasons. This first finding is related to the availability of water in irrigation systems using watering cans, and is related to financial means for fuel and maintenance of the motor pump. In the rainy season, where the amount of water used for irrigation is quite small, water and financial means are relatively less important compared to the dry season. In the dry season, the amount of water used for irrigation increases and thereby also the need for water and financial means. But the availability of water differs according to specific local conditions (distance to water sources, time constraints, etc.). Moreover, some farmers may lack financial means while others still have some capital resources.

In the second finding, the larger distance between minimum and maximum data values and the size of the box in case of irrigation with motor pumps are linked to the sources of water in both cases. As described above, groundwater is the main water source for irrigation with motor pumps and surface water is mostly used in irrigation systems with watering cans. Thus, the availability of water differs: the amount of available groundwater is generally not limited, while available surface water decreases significantly in the dry season. In addition, financial strength can be considered as a limiting factor. Irrigation water from motor pumps is more easily available for farmers but also an increase in usage leads to an increase in cost.

Water requirements for livestock have been calculated in order to evaluate regional impact with the following equation, which has been compiled according to different literature. Although water quality is equally as important as quantity (King, 1983), adequate water quality in this estimation was assumed and therefore neglected.

Water requirements for ruminants depend on the daily intake of dry mass (DM), temperature, race and the current level

Table 3b
Arithmetic averages of the importance for irrigation

	Plant diseases	Water availability	Demand/commercialization	Availability cultivable area	Availability of labor
Grade of importance	1.72	3.24	3.99	3.17	2.88

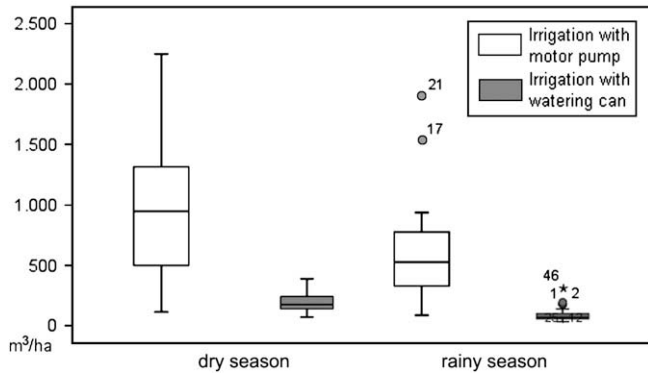


Fig. 5. Water quantity used for irrigation depending on season (m³/ha).

of performance. The higher the water content in feedstuffs, the less additional water is required. The intake of dry mass again depends on the live weight of livestock. Furthermore, temperature affects water requirements per animal and day. At higher temperatures livestock absorb more water per kilogram dry mass, which is considered in the estimation of water requirements (first summer). An accessorily increasing water need emerges during lactation. In the tropics 3 l of water is estimated for one additional liter milk (Legel, 1989).

For pigs, the moisture content of the feedstuffs defines the water requirements per animal and day. However, the moisture content in fodder rations is unknown as pigs are often fed with varying products including waste, and no feed analysis is available. Therefore a constant water requirement is assumed per pig and day. Similar conditions were attributed to poultry, whose daily water needs are stated with 0.3 l per animal (Kirchgeßner, 1997).

These water requirements for all productive livestock in Benin are compiled and assessed differentiated to regions:

$$WQ_i = \sum_r \left(\frac{N_{r,i} \times LW_r}{TLU} \times 6.25 \times (4.303 + 0.0906 \times e^{(0.115 \times \text{temp})}) \right) + 3M \times N_{\text{cows},i} + \sum_m N_{m,i} \times n_m$$

where WQ: water quantity; TLU: tropical livestock unit (250 kg); *i*: region; temp: temperature in °C; *r*: ruminants; *N*: animal numbers; *M*: milk performance; *m*: monogastric animals; *LW*: live weight; *n*: water requirements.

Following the distribution of livestock, the northern departments, Alibori, Borgou and Atacora, show the highest requirements for water in absolute terms. Compared to total precipitation, the amount of required water for productive livestock is quite small. However, local officials often mention in discussions not to forget water requirements for livestock in water balances because animals are obvious users of water and a concurrence for human beings. This is the reason why water requirements of livestock are compared with the needs of human beings. If the average human water consumption is constituted with 20 l per day and capita (WHO, 2000),

which is the aimed target for an individual in Benin, the situation turns out to be as shown in Fig. 6.

In the southern departments the amount of water required for livestock is less than 20% of the water needed for human beings, due to high population density and less livestock. In the two departments Collines and Donga less than half of the water is consumed by livestock than by people. In the northern departments, productive livestock can be an obvious concurrence in water consumption. In Borgou and Atacora, animals need a bit more water than the population and in Alibori livestock consumes twice as much.

3.3. Problems and limiting factors

Regarding the seasonal water sources and quantities some limiting aspects are already apparent. In the scope of the surveys similar problems have been identified for irrigation as well as for livestock management.

Foremost, the high potential of irrigation in Benin is not yet used as described above. The following section tries to give reasons for its slow development. As a result of the partly standardized questionnaires for both experts and farmers, in all types of the investigated irrigation systems, insufficient availability of inputs like pesticides, fertilizers and seeds play a major role in decreasing agricultural production. These inputs were nearly exclusively used in the well-developed and governmentally supported cotton producing sector (CENATEL, 2002). Specific inputs for food crops are expensive and hardly traded (van den Akker, 2000). In addition to this, deficits in the infrastructure such as missing roads, energy and transport

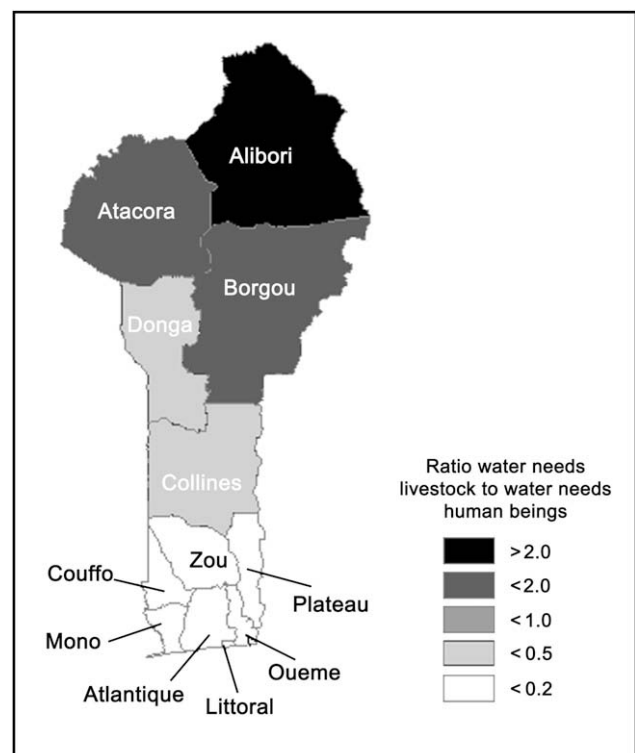


Fig. 6. Water needs of livestock compared to human needs in 2002.

possibilities, as well as difficulties in storage and processing aggravate the commercialization of the products (Beck, 1995).

Water availability was only referred to as a problem by urban and periurban farmers. Nearly 46% of all farmers did not have sufficient water for irrigation. Indeed, all of them used watering cans. In terms of seasonality all farmers indicated that they only suffer from water shortages during the peak of the dry season from January to March.

In particular, large-scale irrigation systems were referred to as having bad management structures and insufficient organization as important constraints. However, the production in the irrigation system in Malanville is identified as the best organized and most efficient (Tonuhewa, 2006).

Farmers and experts also revealed problems of commercialization, particularly in the case of rice. The processing of rice is unorganized. Numerous individual activities with incomplete knowledge or adequate processing techniques result in low quality. In addition to locally produced rice, large quantities of rice are imported from Asian countries at low cost and high quality. Currently, the local rice is not competitive to Asian rice and due to its inferior quality and is rejected by the consumer (Ahoyo Adjovi, 1996; MAEP/PADSE, 2003).

Interviewed farmers of urban and periurban vegetable producing irrigation systems valued five problems depending on importance (1: very important influence; 2: important influence; 3: moderate influence; 4: little influence; 5: no influence). Tables 3a and 3b represent the averaged results in the four investigation areas from 100 questionnaires.

Plant diseases turned out to be the predominant problem for the farmers in the investigated areas. The second most important influence represents labor. Water quantity did not seem to be the biggest problem in the farmer rankings. Commercialization is ranked as the lowest influence. But this result is related to the choice of the investigation areas, which contains the most economically active cities (especially Cotonou and Porto-Novo) in the densely populated south of Benin. In contrast to this, difficulties in commercialization in the Centre and North of Benin and in smaller cities may be assumed.

A similar ranking of water as a limiting aspect could also be found in livestock management. The appraisal of animal keepers and experts in respect to production difficulties are listed in Table 4. Interestingly the first three aspects: forage, diseases and problems with the supply of water, are in the same order and significance for animal keepers and experts.

Table 4
Difficulties in livestock management according to animal keepers and experts

	Animal keepers ^a (%)	Experts ^b (%)
Forage	33.9	25.6
Diseases	24.0	14.7
Water	19.3	10.9
Conflicts	7.0	1.6
Commercialization	–	10.9
Extensive production	–	8.5
Missing consulting, research	–	7.8
Other aspects	10.5	15.5

^a N = 169.

^b N = 129.

With a distinct gap and an unexpected high percentage, problems in feeding rank first. This was unexpected as official programs still concentrate on the abatement of diseases, which are still obvious constraints in production but seemingly better under control than feeding.

Water as limiting production factor is mentioned by nearly 20% of the interviewed animal keepers. But also here, regional differences exist: as southern livestock keepers own wells, only for less than 5% is water sometimes limited whereas the highest share is reached in the central region with around 29%. Thus, water limits production in different regions.

According to a study of COMO (1994), water scarcity occurred in former times only in years with low precipitation, because dense vegetation ensured slow surface run-off. The survey, which was held in the mid 1990s, stated water scarcity and conflicts between farmers and animal keepers due to a growing population, increasing animal numbers, ebbing of sources, blockade of access paths to fountains, forest clearance and the interdiction of watering at public fountains. Watering at wells was traditionally one way to deal with water scarcity besides drawing out sinkholes or seasonal herd peregrination.

Although in the investigated areas water storage basins are not available or used, more and more water storage basins are built to reduce seasonal deficits. But there are many difficulties associated with constructing water storage basins. Size, place and spatial distribution have to be identified and the participation of local people should be guaranteed. Otherwise, water storage basins are not accepted and long-term utilization is doubtful. New water storage basins are able to assure safe water supplies, but according to COMO (1994) they can pose new problems if they are designed larger than 60,000 m³.

Often, basins are constructed for both farmers and animal keepers to help improve the situation. However, post-effects such as conflicts arise when farmers occupy the best fields near the basins hampering free access to the water source for livestock, or too many additional herdsmen with their herds are attracted by the availability of water. The latter causes an excessive demand on pasture, which is not available, and overgrazing and erosion are the consequence (Jahnke, 1982).

These conflicts between farmers and animal keepers sometimes arise, particularly if water resources become scarce in the dry season or rights of access are not clearly defined. Whereas conflicts between animal keepers are barely known, the traditional right regulates that herdsman among themselves must not refuse access to water and pasture to others (COMO, 1994).

4. Conclusions

This paper shows that although water supply in absolute terms seems to be sufficient in Benin, the situation is not consistent regarding seasonal water scarcity in agriculture. Seasonal water problems related to adequate water supplies occur both in irrigation and in livestock management, despite the fact that both play a minor role in Benin's agriculture especially when compared to other West African countries.

Arising seasonal water problems are not the consequence of general water scarcity but more linked to three major problems:

first, the technical equipment and financial means of farmers, second the specific local conditions influencing the access to water sources and the extraction of groundwater, and third the overall low organizational structure of water management.

First, local techniques used by farmers to open up water sources are not adequate to achieve a year-round and continuous water supply. Most of the wells and “marigots” are not deep enough to reach the water-bearing stratum during the dry season. Additionally, current technical equipment for most irrigation systems is very simple and mainly consists of watering cans. The construction of deep wells supplied groundwater and the extension of the currently small irrigation sector has large development potential. With better technical equipment, such as motor pumps, groundwater could be made available to farmers. This development potential can be used because of the availability of natural water resources and non-cultivated land for agriculture as well. Water availability and reliability for agriculture could be noticeably improved. This would help reduce seasonal impacts on farmer’s output and thus stabilize their incomes. Despite the awareness of farmers on irrigation potential and their demand for deeper wells, missing financial means hamper their investment in these technologies. The limited access to credit markets, as well as missing financial securities hinders their ability to raise necessary capital.

These technical and financial problems aggravate the importance of the second aspect in seasonal water problems: the location of the water source. Geographical conditions determine the access to groundwater as to whether it can be easily reached or expensive drilling is needed. In regions where groundwater is not accessible or cannot be opened up easily, seasonal water scarcity is more likely to occur. The geographical location and the natural endowment of water resources are well-known aspects of livestock management, and one of the most relevant points in analyzing adequate water supply. As animal keepers prefer the nearest water source to supply their livestock, distances to water sources differ considerably depending on seasons. In the dry season, distances and therefore the time spent for livestock keeping are greater than during the rainy season.

The third obstacle for efficient water management in agriculture is the low organizational structure of aspects related to water. Urban and periurban irrigation systems, as well as large-scale irrigation systems are not well organized. The importance of organization can be underlined by past experiences which demonstrate that large-scale irrigation systems did have adequate financial and technological means, but were more likely to fail without external help. Moreover, high population growth and changes in diets, especially in (peri-) urban regions, lead to an increasing demand for agricultural products such as rice, which is mainly cultivated with irrigation. In spite of this, problems still exist in the cultivation and the processing of these irrigated products. Therefore, an increase in organization improves water use in irrigation and food security. Better organization may assuage the fact that despite general water availability, water shortages impact agricultural production or give way to conflicts.

The organizational aspect and the regulation of access to water sources are equivalent arguments in the case of livestock husbandry. This is particularly true when transhumant animal keepers from different regions are concentrated in one area during the dry season, and productive livestock is tended at few water sources. Under this situation, competition between different user groups arises easily. Therefore, it is important that in the livestock sector, the organizational structure of producer groups is strengthened. Additionally, newly created water committees in villages should be constantly integrated into the decision process to avoid conflicts and to enable all groups to profit from natural public resources.

Summarizing the analysis of seasonal water demand in Benin’s agriculture, it is recommended that policy makers closely regard the agricultural sector in Benin due to its developmental potential and its necessity regarding population growth. However, the potential for general development and food security only holds true if obstacles of seasonal water use in agriculture, such as for irrigation and water demand for livestock, are well considered.

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