VEGETABLES IRRIGATED WITH STORED RAINWATER FOR HOUSEHOLD FOOD SECURITY

DES LÉGUMES IRRIGUÉS PAR LA PLUIE ENTREPOSÉE POUR LA SÉCURITÉ ALIMENTAIRE DU MÉNAGE

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ABSTRACT

Livelihoods are affected by seasonal water scarcity as vegetables cannot be cultivated in the dry season without irrigation. A wide variety of food crops are needed to maintain a balanced diet, proving proteins, minerals and vitamins. Many households in Africa have vegetable gardens at home which could benefit from stored rain water for irrigation during the dry winter season. Matching the amount of water that can be collected and stored to the water required to produce the vegetables is not easy. SAPWAT3 is a planning and management tool that uses natural resources data to estimate crop irrigation requirements and calculates the area and storage capacity of small-scale rain water harvesting. A vegetable garden of 100 m^2 was planned to produce a combination of legumes, green leafy vegetables and root crops with staggered plantings throughout the year at Nongoma, South Africa, in a summer rainfall area receiving 994mm pa. SAPWAT3 was used to calculate monthly values of water use for optimal vegetable production and to balance the irrigation requirement with stored harvested water. It was shown that one can produce vegetables for a balanced diet from the garden by supplementing the rainfall with water from a 60 m^2 harvest area stored in an 11 m^3 container.

Keywords: household, vegetable irrigation, rainwater harvesting, water requirements

RESUME ET CONCLUSION

Le manque saisonnier d'eau entraîne des conséquences pour la source de revenue, parce que les légumes ne peuvent pas être cultivés sans irrigation pendant la saison sèche. Il y a un grand besoin d'une diversité de cultures vivrières fournissant de la protéine, des minéraux et des vitamines pour maintenir une alimentation saine. Beaucoup de ménages en Afrique qui ont des jardins potagers chez eux, pourraient profiter de la pluie entreposée pour l'irrigation pendant l'hiver sec. Il est difficile d'égaler la quantité de l'eau qui peut s'être accumulée et entreposée à la quantité nécessaire pour la culture de légumes. Le SAPWAT3 est un outil de planification et de gestion qui se sert des données de ressources naturelles pour l'estimation des besoins d'irrigation de la culture. Par le moyen de cet outil, on peut aussi calculer la superficie et la capacité de la récolte de la pluie à petite échelle. Un potager de 100 mètres carrés a été envisagé pour cultiver des légumes variés : des légumes verts à feuilles et des racines comestibles plantés échelonnés au cours d'une année à Nongoma en Afrique du Sud, dans une région de pluie estivale de 994 mm par an. Le SAPWAT3 a été utilisé pour calculer l'usage mensuel de l'eau pour une culture optimale et pour mettre en équilibre les besoins de l'irrigation et de l'eau récoltée et entreposée. Des légumes pour une alimentation saine peuvent être cultivés dans le potager par l'augmentation de la pluie par l'eau récoltée sur une superficie de 60 mètres carrés et entreposée dans un récipient de 11 mètres cube. Cette étude de cas de SAPWAT3 montre qu'il est possible de cultiver des légumes pendant toute l'année à Nongoma, dans une région rurale du Kwazulu-Natal, à condition qu'il y ait une récolte d'eau à petite échelle et qu'une quantité suffisante d'eau puisse être entreposée pour irriguer les cultures pendant l'hiver sec. Pendant l'été, une équilibration d'eau est maintenue dans la région de démonstration. Pour cette raison, le secteur du potager non pas réservé à la culture de légumes sous irrigation, pourrait être utilisé pour cultiver des légumes d'été en terre aride. Une telle approche peut fournir à une famille une provision continue de légumes frais. Le plus grand problème pour une famille très pauvre serait des frais pour fournir un récipient pour la récolte de l'eau, mais le problème pourrait être réglé par une sorte d'allocation sociale afin d'aider les gens à installer le récipient.

INTRODUCTION

Water scarcity affects rainfed crop production and directly threatens the livelihood of millions of people, particularly in developing countries, and specifically in sub-Saharan Africa. Seasonality of rainfall is an important contributor to this problem and usually leads to a problem of malnutrition due to a diet lacking in mainly protein and vitamins, as well as not enough food to satisfy the daily requirement. The obvious solution is to store water on a small scale for irrigation purposes during the dry season. Therefore it is important to revive some of the traditional practices such as water harvesting systems, so that this water can be used for vegetable production (Alem, 1999; Metro-Water, 2005). One such method is to collect the rain from the roof of the house and store it in a container for later use as is done in many African countries (DTU, 1999). However, mostly extreme poverty of rural communities makes this a non-feasible option, unless some form of social welfare system assists with construction of storage facilities (Botha, et al., 2007; Van Heerden et al., 2008; Woyessa et al., 2006).

Traditional water supply technologies have for many centuries been able to meet the needs of local populations, such rainwater harvesting systems are one of the options to ensure sustainability (Alem, 1999; Gould and Nissen-Petersen, 1999). Households should also be cultivating food crops to be able to supply much of their own needs for fresh vegetables. This will ensure a healthy nutritious diet and that the children will be able to grow and learn well in school. However, most households in Africa have limited space in the backyard for cultivation of vegetables. Therefore one needs to optimize the area to collect water, mostly the roof, and that to cultivate vegetables as well as balancing other recreational needs for space around the home.

The problems of providing a secure supply of water for small-scale vegetable production, such as backyard production are multi-layered. Firstly, to calculate the amount of water required to supplement the rainfall. Secondly, the volume of water storage tanks capacity needed to meet this irrigation requirement. Thirdly, the size or area of the catchment needed to harvest sufficient water from the rain events to produce enough water to meet requirements during the dry spells or dry season. Fourthly, to calculate the potential production of each variety of vegetable and thus the area needed for the garden. All these factors complicate the planning of the out-of season backyard vegetable production in terms of the combination of varieties of food crops and the quantity of water needed.

SAPWAT3 is a computer tool that can be used to address these issues and to estimate the irrigation water requirements for food gardens, as well as estimating the requirements for small-scale rain water harvesting area and the storage capacity required for the harvested water (van Heerden et al., 2008). This tool was used to do a theoretical case study to illustrate the issues that need to be taken into account in the planning of vegetable production under irrigation in backyard situations in rural areas in southern Africa. The objective of this study was to plan a food garden that uses limited water yet produces food for a household utilising the collected rainwater.

METHODOLOGY

SAPWAT3 was used to estimate irrigation water requirements for a vegetable garden with small-scale water harvesting and the required storage capacity for a typical backyard in Nongoma (31º 40’ E; 27º 50’ S) in northern KwaZulu-Natal in South Africa. The weather station used for the estimates is a virtual weather station positioned at the centroid of the quaternary river drainage region W22g (Lynch, 2004). The Köppen climate for the area is mild (mesothermal), humid with hot summers and summer rainfall. The long-term climate detail can be seen in Figures 1 and 2. Average rainfall is 994 mm, but a water balance deficit (ETo > Rain) is found from March to October, which precludes vegetable production unless the vegetables are irrigated (Fig. 1). Frost does not occur in this area (minimum temperature > 3°C, Fig. 2) therefore the production of vegetables should be possible all year around. However, for some crops, like onions, the winters are not cold enough for successful production, as all months are above 10°C (Fig. 1), a factor that should be kept in mind in the planning of a vegetable production system. The vegetables were selected and calculations done for the annual water requirement based on an available area in an average backyard of 100 m^2 per household.

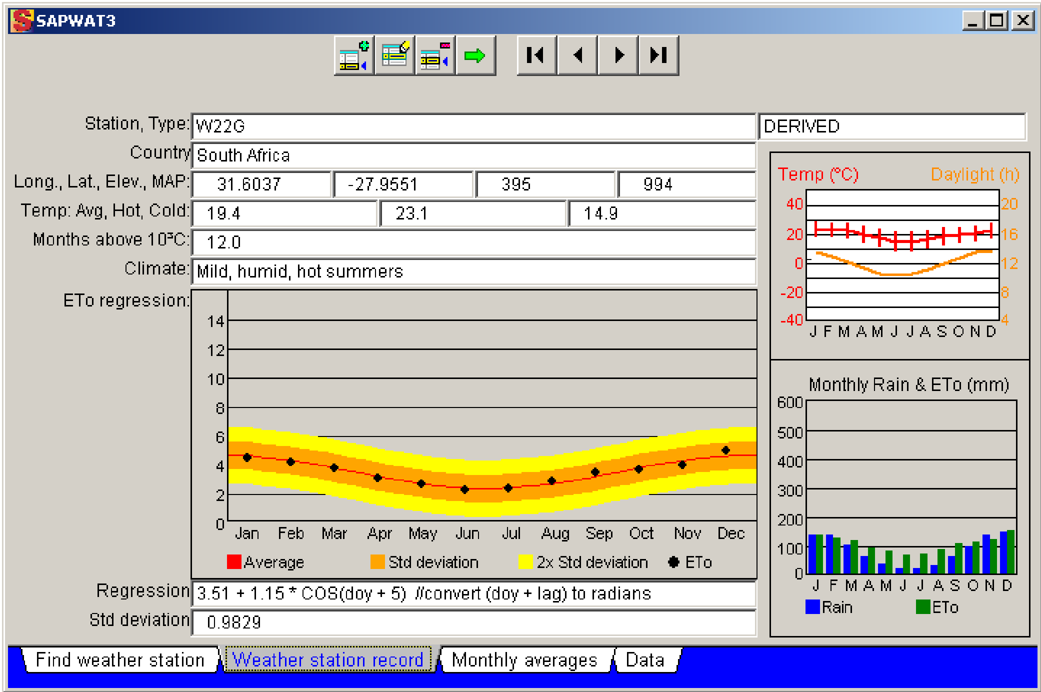
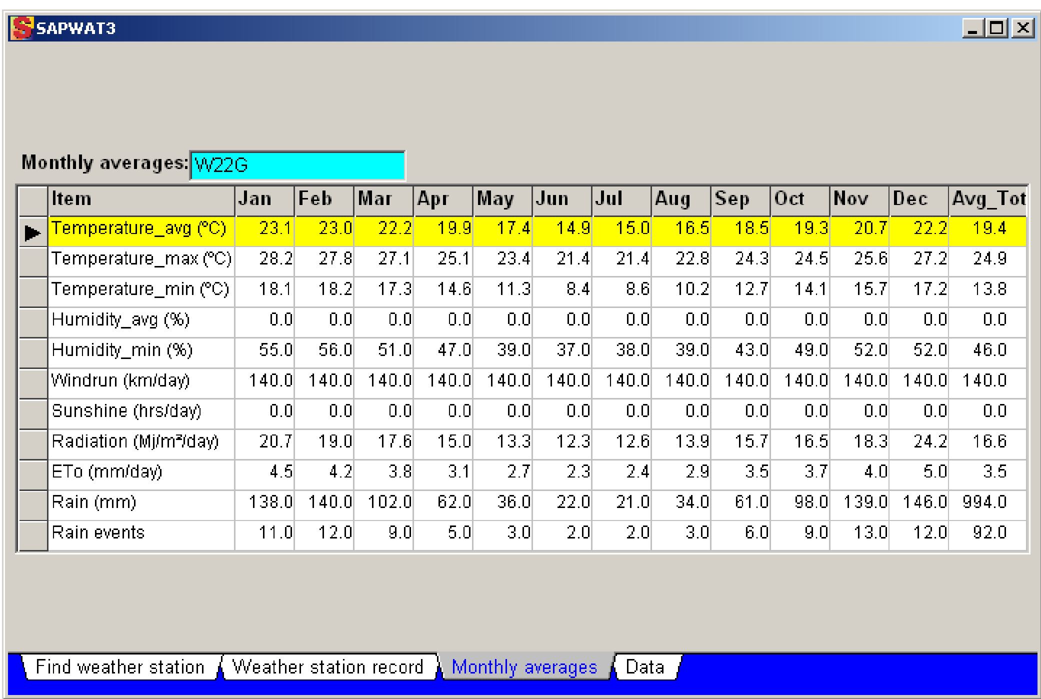


Figure 1. Long-term climate for weather station W22g which represents Nongoma, in KwaZulu-Natal

Figure1. Climat à long terme pour la station météorologique W22 qui représente Nongoma à Kwazulu-Natal



Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg_Tot
Temperature_avg (ºC)	23.1	23.0	22.2	19.9	17.4	14.9	15.0	16.5	18.5	19.3	20.7	22.2	19.4
Temperature_max (ºC)	28.2	27.8	27.1	25.1	23.4	21.4	21.4	22.8	24.3	24.5	25.6	27.2	24.9
Temperature_min (ºC)	18.1	18.2	17.3	14.6	11.3	8.4	8.6	10.2	12.7	14.1	15.7	17.2	13.8
Humidity_avg (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Humidity_min (%)	55.0	56.0	51.0	47.0	39.0	37.0	38.0	39.0	43.0	49.0	52.0	52.0	46.0
Windrun (km/day)	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0
Sunshine (hrs/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Radiation (Mj/m²/day)	20.7	19.0	17.6	15.0	13.3	12.3	12.6	13.9	15.7	16.5	18.3	24.2	16.6
ETo (mm/day)	4.5	4.2	3.8	3.1	2.7	2.3	2.4	2.9	3.5	3.7	4.0	5.0	3.5
Rain (mm)	138.0	140.0	102.0	62.0	36.0	22.0	21.0	34.0	61.0	98.0	139.0	146.0	994.0
Rain events	11.0	12.0	9.0	5.0	3.0	2.0	2.0	3.0	6.0	9.0	13.0	12.0	92.0

Figure 2. Mean monthly weather data for Nongoma, in KwaZulu-Natal, based on 50-year record

Figure 2. Moyenne des données météorologiques mensuelles, basées sur des récits, accumulés sur une période de 50 ans pour Nongoma au Kwazulu Natal

The water harvest module of SAPWAT3 was used to determine the size of the water harvest area needed as well as the required water storage volume or tank size. It was assumed that the household would require a monthly amount of 3.8 m^3 water for domestic use and that the household would produce 1-2 m^3 grey water per month that could be recycled as irrigation water. Furthermore the required water harvesting area should not exceed 60 m^2, on the assumption that the roof area in rural areas seldom exceeds this size.

RESULTS AND DISCUSSION

Vegetable Crops

The vegetables selected for this area and used in the case study were beans, beetroot, butternut, spinach and green maize. All the crops, except for the butternut will be sown with staggered planting dates and with a planting size of 15 m^2 so as to supply the needs of the family. The growth of butternut pumpkin / squash is indeterminate and so will continue to grow and provide fruits over an extended period of time.

As the bean crop will provide protein to the household, it was planted three times during the summer months, namely in September, November and January. The maize (mealies) will be grown as a green maize crop to be eaten as ‘corn-on-the-cob’ either freshly boiled or roasted over the open fire and not mainly for dry maize as a staple food of maize meal for porridge. This is due to the limited space available in the typical backyard, however, some of the cobs maybe left and dried to supplement the maize meal to be bought during the year to supply the required carbohydrates in the diet.

During the mild winter, beetroot and cabbage can be grown successfully. As beetroot is a short season crop it will be planted three times during March, May and August. Cabbage can stay on the land longer and is planted twice in autumn (March) and in late winter (August) and should supply sufficient for the household, possibly with some excess to sell. Spinach is a good source of nutrients and can continue to produce a crop due to serial harvests so it will be planted in spring (October) and autumn (March) to allow a continuous supply of leafy green vegetable all year round. The approximate growing periods, and planned area where each crop is to be grown is shown in Table 1. One does not actually need a total of 195 m^2 for these vegetables but 100 m^2 as they can be grown using double cropping and under various rotations on a single piece of land however that detail is not given. Crops not selected could be grown interchangeably with selected crops without significantly affecting the total irrigation requirement, provided that the crop that replaces a selected crop has the same growth characteristics as the crop being replaced.

The potential yields shown in Table 2 are based on good commercial vegetable production levels in South Africa. In general, lower yields are usually expected in backyard production due mainly to less dense plantings and poor irrigation management that allows some water stress to occur (De Lange, 1994).

Table 1. Vegetable growing chart for irrigated vegetables at Nongoma
Tableau 1. Carte pour illustrer des récoltes de légumes irrigués à Nongoma

Crop	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Area (m^2)**
Beans	■	■	■										15
Beans									■	■	■		15
Beans	■										■	■	15
Beetroot			■	■	■	■							15
Beetroot					■	■	■	■					15
Beetroot								■	■	■	■		15
Butternut	■									■	■	■	15
Cabbage			■	■	■	■							15
Cabbage								■	■	■	■		15
Mealies / green maize	■	■	■	■									15
Mealies / green maize									■	■	■	■	15
Spinach			■	■	■	■	■	■	■				15
Spinach	■	■	■	■						■	■	■	15

Table 2. Expected potential yield based on commercial vegetable production

Tableau 2. Rendement potentiel prévu, basée sur des récoltes commerciales de légumes

Crop	**Expected yield (kg/15 m^2)**
Beans	90
Beetroot	100
Butternut	60
Cabbage	200
Mealies / green maize	90
Spinach	350

Irrigation Requirements

The SAPWAT3 estimates of irrigation requirements for these crops were made with the following stipulations for the basic natural resources in the area. The irrigation system selected was flooded basins as this is the best approximation for the short furrow approach generally found in rural areas as it is simple to construct and can be managed with a fair level of efficiency (De Lange, 1994). The soil selected is loam, with an effective depth of 800mm. The irrigation management was based on total extraction of readily available water and a refill of 20 mm per event. This is done in an effort to imitate observed practice where a crop is watered when the first signs of stress are observed and irrigation is not by refilling to field capacity but giving less than the optimal crop irrigation requirements. However, for this case study no water stress situations were imitated and rainfall is included in the water balance equation. The irrigation requirements for each of the crops and plantings are shown in Table 3.

Table 3. Irrigation requirements (mm) for vegetables grown at Nongoma

Tableau 3. Besoins d'irrigation (mm) pour la récolte de légumes à Nongoma

Crop	Plant date	J	F	M	A	M	J	J	A	S	O	N	D	Total
Beans	15/01	0	9	32	0	0	0	0	0	0	0	0	0	41
Beans	15/09	0	0	0	0	0	0	0	0	32	22	30	0	98
Beans	15/11	36	0	0	0	0	0	0	0	0	0	0	24	62
Beetroot	15/03	0	0	0	0	36	17	0	0	0	0	0	0	60
Beetroot	15/05	0	0	0	0	0	0	49	34	0	0	0	0	83
Beetroot	15/08	0	0	0	0	0	0	0	0	24	49	0	0	79
Butternut squash	15/11	66	6	0	0	0	0	0	0	0	0	27	49	152
Cabbage	15/03	0	0	25	8	33	63	24	0	0	0	0	0	161
Cabbage	15/08	0	0	0	0	0	0	0	28	28	42	43	22	174
Mealies (Corn-on-the-cob)	15/01	0	1	45	59	39	0	0	0	0	0	0	0	161
Mealies (Corn-on-the-cob)	15/09	34	0	0	0	0	0	0	0	1	2	47	92	187
Spinach	15/03	0	0	12	11	31	62	81	89	53	0	0	0	351
Spinach	15/10	61	60	63	38	0	0	0	0	0	4	1	41	297

Water Harvesting

The results shown in Figures 3 and 4, indicate that the assumed roof area will provide enough water for the vegetables grown as planned. A water storage capacity of 11 m^3

(Fig. 3) in the form of an enclosed tank, is required. Storage could take place in a pond, but storage capacity required would then be increased to at least 17 m^3 because of the lower efficiency of such storage due to seepage and evaporative losses.

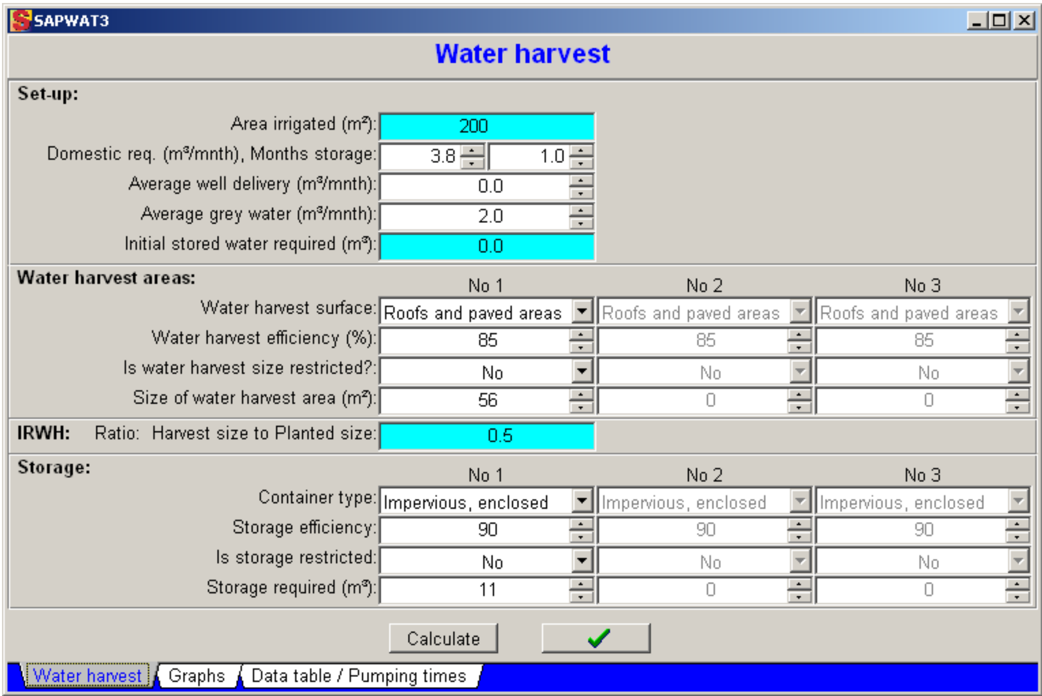


Figure 3. The water harvesting set-up screen, showing the required water harvest area and required water storage volume
Figure 3. Grillage pour la configuration de la récolte de l'eau, indiquant la surface et le volume nécessaires pour la récolte et l'entreposage de l'eau

The monthly water balance graphs for the planned vegetable crops are shown in Figure 4. It gives a water balance deficit from May through to October which needs to be supplied from stored water so as to continue to irrigate the crops grown during that period. The weather station data shows that a negative water balance starts in March according to the long-term rainfall and evaporation data. But as rain water received during the summer is stored in the soil profile it can be used by the crops for March and April resulting in the vegetable garden only showing a negative water balance from May onwards.

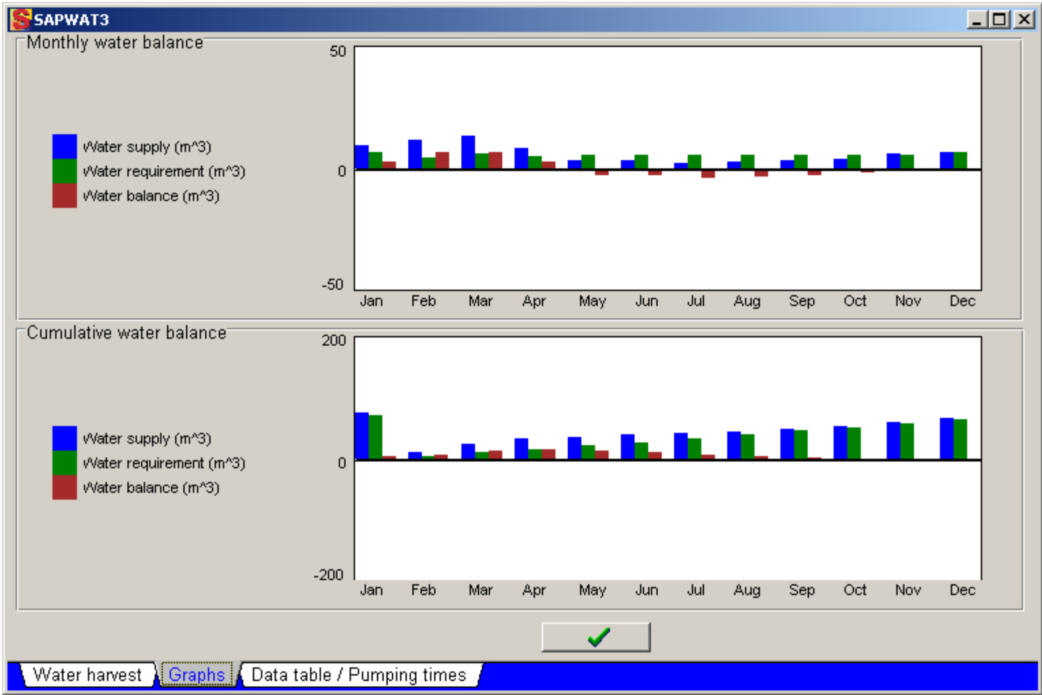


Figure 4. The water balance diagram for Nongoma from SAPWAT3

Figure 4. Schéma d'équilibrage d'eau à Nongoma, obtenu de SAPWAT3

CONCLUSIONS

A household size vegetable garden was successfully planned for Nongoma using staggered plantings of 15 m^2 each of beans, spinach and green maize in the spring and summer and beetroot and cabbage in the winter. As butternut continues to grow it was only planted once. This garden is able to produce adequate food for a balance diet for a family with a surplus to sell to other members of the community. The vegetables have a whole range of different irrigation water requirements according to the planting dates and expected rainfall during those months. The spinach planted on 15 March needed the most water, 351mm, and the bean planted on 15 January needed the least irrigation, requiring only 41mm due to the higher rainfall and shorter growing season. The planned vegetable garden can be irrigated from a 17 m^3 storage tank used to collect summer rain water which is then used from May till October for irrigation.

This SAPWAT3 case study shows that it is possible to grow vegetables throughout the year at Nongoma in a rural area in KwaZulu-Natal, provided that small-scale water harvesting is done and that enough water can be stored to irrigate the crops during the dry winter period. During the summer months a positive water balance is found in the demonstration area, and therefore the vegetable garden area not used for irrigated vegetable production could also be used for dryland production of summer food crops. An approach like this can provide a continuous supply of fresh vegetables to a family. The biggest problem for a very poor family could be the cost of providing the rain water storage container, but that problem could be alleviated by some form of social grant to assist the family in setting up the storage facility.

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