Research Application Summary

Modelling of runoff water harvesting, storage and irrigation for dry season bean production

Singa, D.D.[1], Tumbo, S.[1], Mahoo, H.[1], Rwehumbiza, S.[1] & Lowole, M.[2]
[1]Department of Agriculture Engineering and Land Planning, Sokoine University of Agriculture, BP: 3001, Morogoro, Tanzania
[2]Soil Science Department, University of Malawi, Bunda College, Box 219, Lilongwe, Malawi
Corresponding author: dodomamwasinga@live.com; dodoma1mwasinga@yahoo.com

Abstract

Productivity of Common bean (*Phaseolus vulgaris* L.*)*, an important component of farming systems in smallholder agriculture of sub-Saharan Africa, remained stagnant or even declined over the years, because of major problems such as drought. The present study aims at modeling runoff rainwater, seasonal storage of harvested water in an open surface reservoir and determination of water-bean productivity in drought prone sub Saharan Africa, using Ukwe Area in Malawi as a case study site. Rational technique based on discharge attributes of seasonal rainfall and catchment area will be used to develop a stored water prediction model. This in turn will be compared with irrigation volume requirement model component as the season progresses. A relationship between applied water and bean water productivity is being established. The yield model simulating component uses input data of evaporation (mm), temperature (^{0}C), relative humidity (%), wind speed (Km/day), Saturation deficit (kPa), and Solar radiation (MJM-^{2}day^{-1}) on daily basis, and soil types and bulk density of the soil (g/cm^3), crop leaf area (m^2/kg), maximum daily root depth (mm), grain number and grain weight (g) on a weekly basis. Preliminary results have revealed that runoff water, long term open surface storage and water-bean productivity can be modeled using climate factors, catchment attributes, reservoir characteristics, and field and crop parameters. Measured and estimated runoff showed correlation of over 90%.

Key words: Beans, catchments, coefficient of correlation, modeling runoff rainwater, seasonal water storage, open surface reservoir, Ukwe area, water-bean productivity runoff relationship

Résumé

La productivité du haricot ordinaire *(Phaseolus vulgaris* L.*)*, une composante importante des systèmes agricoles dans l'agriculture à petite échelle de l'Afrique sub-saharienne, est restée stagnante, voire même a diminué au fil des ans, à cause de problèmes majeurs tels que la sécheresse. La présente étude vise à modéliser les eaux de pluie liées au ruissellement, le stockage saisonnier de l'eau collectée dans un réservoir de surface ouverte et la détermination de la productivité eau-haricots en Afrique sub-saharienne sujette à la sécheresse, en utilisant la région d'Ukwe au Malawi comme un site d'étude de cas. La technique rationnelle basée sur des attributs de décharge des pluies saisonnières et le bassin hydrographique seront utilisés pour développer un modèle de prédiction de l'eau stockée. Ceci sera à son tour comparé par rapport à la composante du modèle d'exigence de volume d'irrigation à mesure que progresse la saison. Une relation entre l'eau appliquée et la productivité eau-haricot est en cours d'établissement. Le composant simulant le modèle de rendement utilise les données d'entrée de l'évaporation (mm), la température (0 ° C), l'humidité relative (%), la vitesse du vent (km / jour), le déficit de saturation (kPa), et le rayonnement solaire ($MJM^{-2}day^{-1}$) sur une base quotidienne, et les types de sol et la masse volumique du sol (g/cm3), la surface foliaire des cultures (m^2/kg), la profondeur maximale quotidienne des racines (mm), le nombre de grains et le poids des grains (g) sur une base hebdomadaire. Les résultats préliminaires ont montré que les eaux de ruissellement, le stockage à long terme de surface ouverte et la productivité eau-haricots peuvent être modélisés en utilisant les facteurs climatiques, les attributs du bassin versant, les caractéristiques des réservoirs, et les paramètres du champ et des cultures. Le ruissellement mesuré et estimé a montré une corrélation de plus de 90%.

Mots clés: Haricots, bassins versants, coefficient de corrélation, modélisation du ruissellement des eaux de pluie, stockage saisonnier d'eau, réservoir de surface ouverte, région d'Ukwe, relation de ruissellement, productivité eau-haricots

Background

Common beans are an important food and cash crop in sub-Saharan Africa. However, production of the crop is threatened by increasing droughts (Eriksen *et al.*, 2008). The vulnerable communities in these areas do not have the ability to integrate soil and water management aspects into the normal farming and natural resource systems due to lack of decision support system in rain water harvesting, storage and irrigation technologies. Mzirai *et al.* (2001) state that use of computer simulation models is the most convenient way of circumventing the time consuming and expensive problems associated with on-site experiments. In other agricultural sectors, decision support systems have been developed and successfully used in specific problem domain (Larbi, 2011).

Literature Summary

Studies on rainwater harvesting by Reij (1991) in Somalia, and Kiome and Stocking (1993) in Kenya have related the water harvesting practice to crop production. Harvested and stored runoff water can be used for irrigation through supplementation during dry spells and as sole water source during the dry season (Finkel and Segerros, 1995). Results from small scale experiments in Central Malawi Plains have shown positive relationship between harvested watershed runoff and rainfall. Thus, runoff water harvesting technique can contribute to food security through irrigation of beans and maize (Singa and Chirambo**,** 2008). Currently no model reviewed has been functional for both harvested open surface water storage and irrigation of common beans, hence the rationale for this study.

Study Description

The current study is being carried out in Ukwe Area, Lilongwe North–West, Malawi in an area 1150 m above sea level. The area occupies flat *dambos* with most predominant soil textural class of sandy loam. During the winter and dry seasons temperatures range from 18 to 24^{o}C with low relative humidity, picking up just before the rains to 29^{o}C, during late November. Main methodology will involveed assessment of catchment area attributes for runoff rainwater, measuring and calculating of volume of water harvested and determination of irrigation water and crop water productivity. The conceptual framework of the water harvesting, storage and irrigation is shown in Figure 1.

Research Application

The runoff water harvested has been found to be linearly related to seasonal rainfall amount with coefficient of correlation of greater than 0.5 (Fig. 2).

The preliminary results have shown high correlation between actual (measured) runoff dependent stream flow and the computed one (over 90 %). This demonstrates reliability of the model calibration functions (Fig. 3).

The crop design rainfall for the area was 600mm. Initial irrigation results for crop establishment and vegetation have shown that to irrigate one hectare of beans runoff from 7.7 ha is required. The catchment area (11 ha) hence sufficed. Bean crop water productivity is being computed.

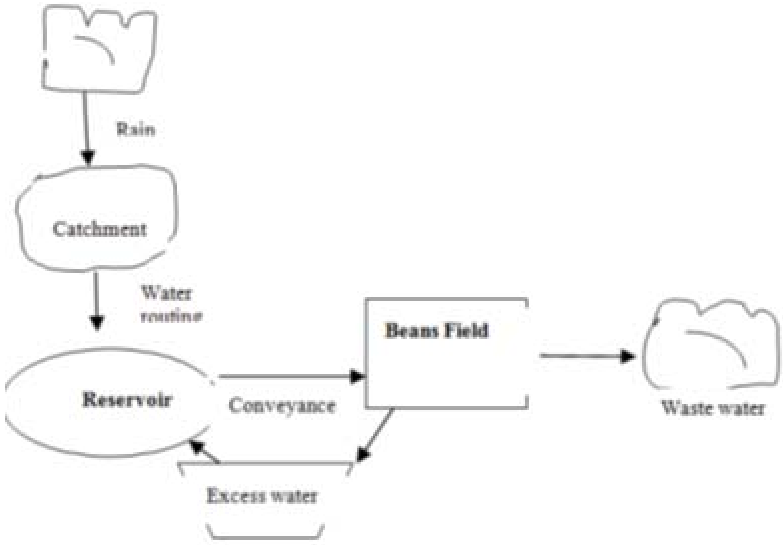

Figure 1. A sketch of the conceptual framework of harvested water and use on a bean crop.

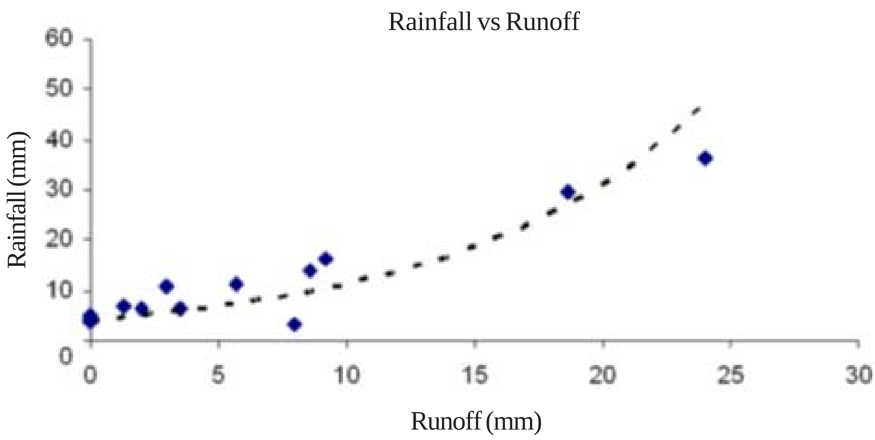

Figure 2. Rainfall in relation to runoff towards reservoir at Ukwe.

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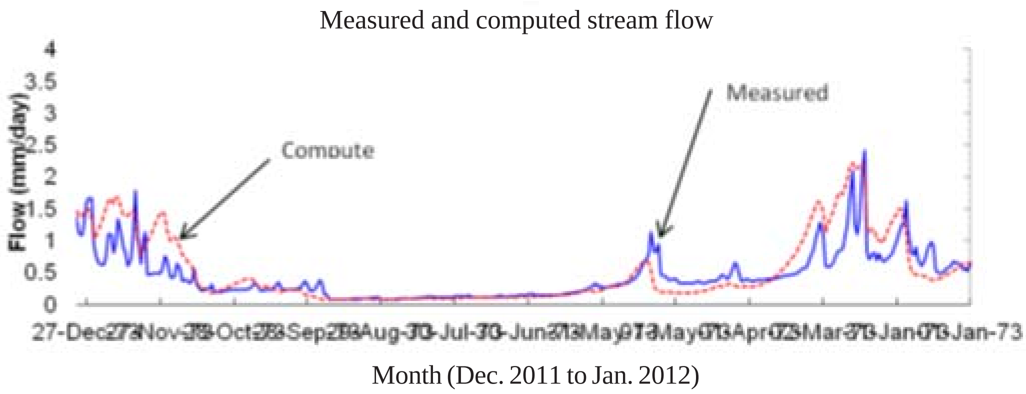

Figure 3. Comparison between actual and computed stream flow into reservoir.

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