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PT Model as a Tool for Studying Farming and Conservation Measures in High Slope Areas: A Case Study of Vidunda Village in Kilosa District

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Background

Vidunda village is in Mikumi division, south of Kilosa Township. It is located at latitude 7º35’ S and longitude 37º02’E and lies at an altitude of approximately 795 metres above mean sea level. The village is situated on a hilly area with high slopes of between 35% - 45%. The soil type is sandy loam. People in this village depend on agriculture for their livelihood. Crops cultivated include maize, beans, bananas, coffee and horticultural crops. Maize is the main staple food. The area receives a seasonal rainfall of between 300mm to 500mm, which is enough for production of many crops especially maize. However, most farmers in this village face food shortages because of the low yields from their farms. The average yield of maize is 0.3 t/ha using conventional farming.

The main reason for the low yields was not well known to district officials. The agricultural extension officers at the district thought that the solution is for farmers to shift to another area especially in the lowlands rather than staying in the mountainous areas. The reason for the advice was based on the fact that due to the steep slopes then automatically the yields will be low because most of the rainwater normally ends up as runoff instead of infiltrating into the soil. On the other hand, the agricultural extension officers thought that if farmers decide to stay then they should adopt terraces in the area because the yield will automatically increase. In short, the problem of low yield was simply attributed to poor adoption of terraces by farmers.

In order to understand the reasons for the low yields, an investigation was required. Under conventional methods, the investigation would have involved setting up experiments to prove that really rainfall ends up as runoff water causing low yields, which farmers had been experiencing. Instead of that option, use was made of the use of agrohydrological models, PARCHED-THIRST (PT) model, which is capable of simulating real systems as long as correct information is fed into the model. Agro hydrological models are also useful because they can be used to simulate many years as long as the weather data for respective years is available. With such information, a proper picture can be drawn and appropriate decisions made rather than performing actual field experimentation or making decision based on speculations. Therefore, PT model was seen as an appropriate tool to use in investigating the reason for the low yields in Vidunda village.

In this case study, therefore, the PT model is used to investigate the reason for the low crop yields and further demonstrate the effect of various soil conservation measures on crop yields, from which farmers could be advised for best option to adopt in order to improve the maize yield and conserve soil and water.

The PARCHED-THIRST Model

PARCHED-THIRST stands for **P**redicting **A**rable **R**esource **C**apture in **H**ostile **E**nvironments **D**uring **T**he **H**arvesting of **I**ncident **R**ainfall in the **S**emi-arid **T**ropics. PARCHED-THIRST model is a user-friendly, process-based model, which combines the simulation of hydrology with growth and yield of a crop on any number of distinct or indistinct runoff producing areas (RPA's) and runoff receiving areas (RRAs). It is a distributed model, which simulates the rainfall-runoff process, soil moisture movement and the growth of sorghum, rice, maize and millet in response to daily climate data. The first version of PT (PT v1.0) simulated only maize under micro-catchment RWH. Version 2 (PT v2.0) includes the simulation of rice and macro-catchment systems up to the hillside or small catchment scale. It comprises a number of components (Figure 1) as described in the following sub-sections.

- An interface which allows users to input, output and analyse data, set options and run the model (Young et al., 2001)
- Data pre-processing to minimise data input requirements;
- Soil moisture and crop growth simulation,
- A runoff prediction component

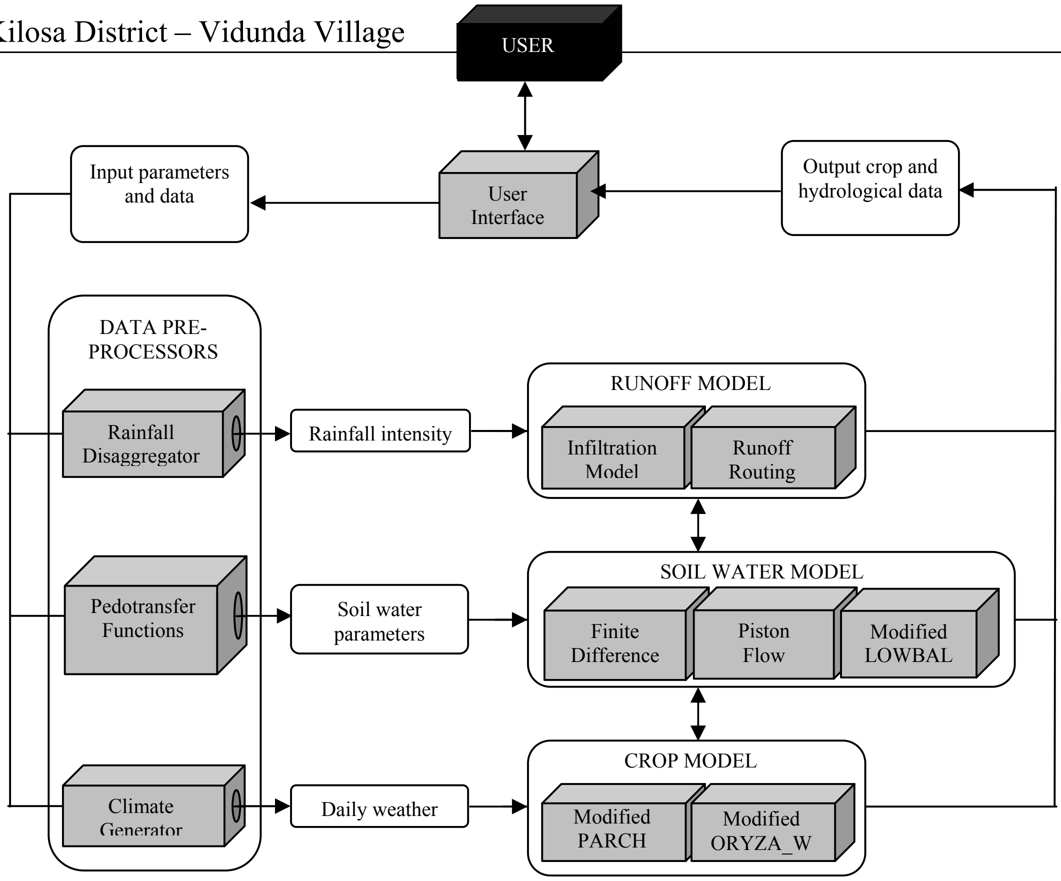

Figure 1. Interaction between the components making up the PARCHED-THIRST model.

Methodology

Field visit and simulation of PT model were used to obtain information on the reasons for low yields in the Vidunda village. The details are provided in the following sub-sections.

Field Visit

A team of researchers from PT Help Office at Sokoine University of Agriculture and Extension officer from Kilosa District Agricultural Office visited Vidunda village. The aim of the visit was to collect information that was needed for the investigation of the low maize yields. The visit included general observation of the forest, cultivated and abandoned areas and discussion with farmers on the problem of low crop yields and their general soil and water conservation measures that they undertake. Figure 2 shows the discussion between researchers, extension officer and some farmers in Vidunda village during the visit.

Figure 2. Farmers at Vidunda village discussing with a researcher (5th from left) from the PT Help Office and agricultural extension officer from Kilosa (1st from left).

During the visit, farmers explained that the knowledge on soil and water conservation was introduced to few key farmers but they failed to adopt it. The field visit in different farms in Vidunda village revealed that almost all the farms located on the steep slopes do not have soil-water conservation measures such as contours and terraces. Furthermore, these farms have shallow depths (less than 30 cm) leading to poor crop stand (Figure 3). The lack of soil and water conservation measures might have lead to increased runoff and erosion and hence reduced soil depth.

In other farms where the slopes are gentle and farmers leave crop residues in their fields after the harvest, erosion was minimum and the soil depth is deeper hence there was a better crop stand (see in Figure 4).

Figure 3. Poor crop stand caused by continuous farming in slopes without conservation measures

Figure 4. Good crop stands where farmers leave crop residues after harvesting

It was also realized that most of the soils of Vidunda village are very steep as it is seen from the photograph below (Figure 5). The topsoil has been washed by runoff leaving behind a lot of stones with shallow depths, which are not suitable for agriculture. This is a typical result of continuous cultivation on high slopes without soil and water control measures leading to low crop yields.

Figure 5. A typical example of continuous cultivation on slopes without soil erosion control measures

However, as it can be seen from Figure 6, some few farmers have implemented some soil control measures (e.g. bunds, terraces etc.). The area with soil and water conservation measures, Figure 6, shows a good plant stands than areas without any conservation measures.

Figure 6. Cultivation using soil control measures (terraces inside the red circle), contours (on the left of the terraces) and without conservation measures at the top.

Therefore, the low crop yields in Vidunda might have been caused by the lack of soil and water conservation measures that led to reduced soil depth in the farms located in the steep slopes due to erosion. Therefore, the simulation of scenarios using PT model will involve simulation of maize yields with a deeper soil depth, shallow depth and with different types of soil and water conservation measures.

Collection of Input Data for PT Model

The input data required for running the PT model include weather and soil profile data. Weather parameters required are rainfall, evaporation, maximum and minimum temperatures, relative humidity, wind speed, saturation deficit and radiation. Weather data for years 2002 to 2005 were obtained from Kilosa District Agricultural Office. Soil profile data used was obtained from Ilonga Agricultural Research Institute and included the following parameters: Soil texture, soil bulk density and initial soil water. Maize variety (TMV1) data used included length of growth stage, specific leaf area, and rooting depth. This data is in-built in the PT Model.

Simulation of the Actual Situations and Conservation Measures

In order to determine reasons for low yields and suitable soil and water conservation measures, different simulation scenarios were considered. Simulations scenarios that were performed included *conventional tillage with deeper soil depth (90 cm) and shallow depth (30 cm)* and the following soil and water conservation measures were also simulated: *contour bunds, terraces and terraces with bunds*. For every simulation scenario seasonal rainfall, runoff and maize yield were recorded in a table for analysis and interpretation.

To represent terraces with the PT Model, a number of profiles are connected in series, whereby each profile symbolizes a level of the field on the sloping terrain. Figure 7 shows a photograph of actual terraces and Figure 8 shows the PT Model representation of terraces.

Figure 7 Stone terraces in the Makanya sub-catchment in Kilimanjaro Region.

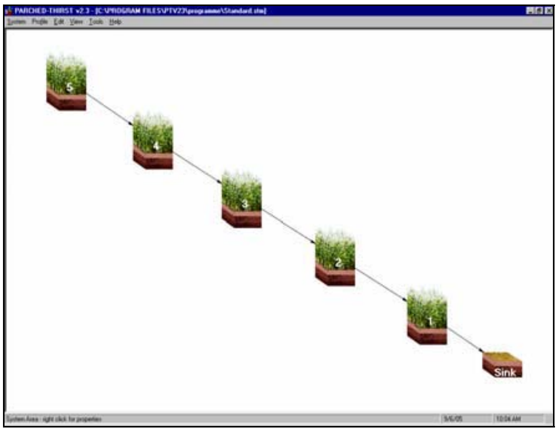

Figure 8 Modeling/presenting terraces in Figure 7 in the PT model.

Simulation Results

Rainfall

Vidunda village has one cropping season and the annual rainfall is between 800mm to 1250mm while the seasonal rainfall is between 300mm to 500mm per season (as shown in the Figure 9). The information that is provided in Figure 8 shows that the higher the annual rainfall the higher is the cropping season rainfall, which is an expected scenario in most cases. The rainy season starts from January to May followed by the dry season that starts from June to November where some few farmers practice traditional irrigation methods to grow maize and horticultural crops as off-season crops.

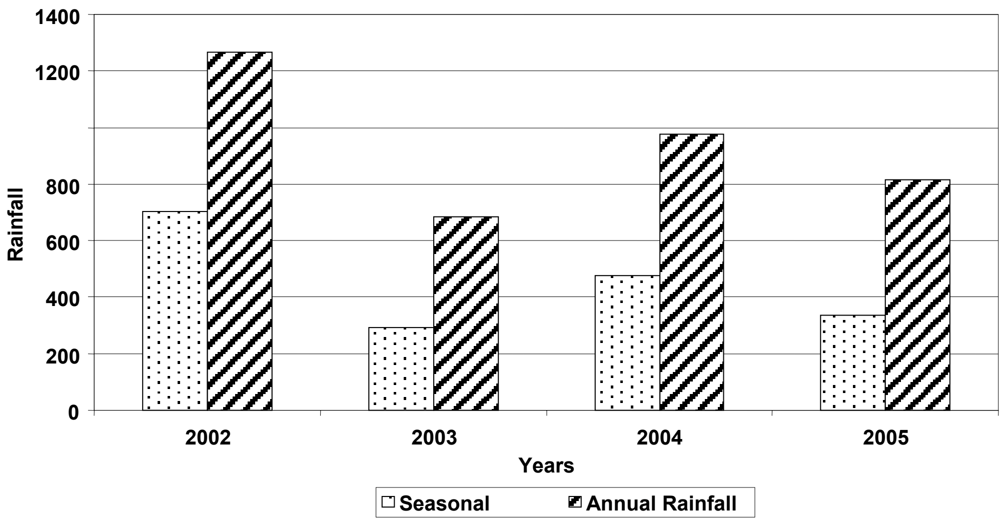

Figure 9. Seasonal and annual rainfall for Vidunda village.

Maize Yield under Different Soil and Land Management Scenarios

Table 1 shows maize yield obtained under conventional tillage with 90 cm and 30 cm soil depths, which are deeper and shallow depths respectively; also maize yield under contour farming, under terraces and terraces with bunds. Comparison of yield on deeper and shallow soil depths shows yield under deeper soil depth to be significantly higher compared to the shallow depth with exception of year 2002. Comparison of yields between conventional tillage with 90 cm soil depth and the three soil conservation measures (contour bunds, terraces and terraces with bunds) shows no difference. This somehow shows that with deeper soil depths conservation measures have no significant impact on yield.

Therefore, it can be deduced from Table 1 and the field visit that the low yields, which Vidunda farmers get, is mainly caused by the effect of shallow soil depth, which are even less than 30 cm rather than other factors. It is therefore obvious that the continuous farming on steep slopes without any conservation measures has reduced the soil depth mainly due to runoff/erosion where by the topsoil has been eroded leaving unfertile bare soil behind with stones.

Table 1. Simulated maize yield for different conservation measures and soil depths.

Conservation Measures	**Maize Yield (t/ha)**			
	Year 2002	**Year 2003**	**Year 2004**	**Year 2005**
Deeper Soil Depth (90 cm depth)	0.8	0.5	0.5	0.4
Shallow Soil Depth (30 cm)	0.7	0.2	0.2	0.2
Contour Bunds (90 cm depth)	0.8	0.5	0.5	0.5
Terraces (90 cm depth)	0.8	0.5	0.6	0.3
Terraces with Bunds (90 cm depth)	0.8	0.5	0.5	0.4

Runoff Generation

From simulation results, it was observed that, conventional farming in steep slopes produce more runoff compared to terraced and contoured farms (Figure 10). Normally the higher is the runoff the higher is the erosion. Terraces reduce surface runoff/erosion because slope is reduced, soil roughness increased. The other conservation measures are not seen in the Figure 10 because they resulted in zero runoff. The two methods had bunds in addition to terraces and contours. These bunds allows runoff water to pond and therefore to infiltrate slowly into the soil. Given the fact that the amount of seasonal rainfall is about 600 mm and in most cases less, bunds intercepted the runoff water completely.

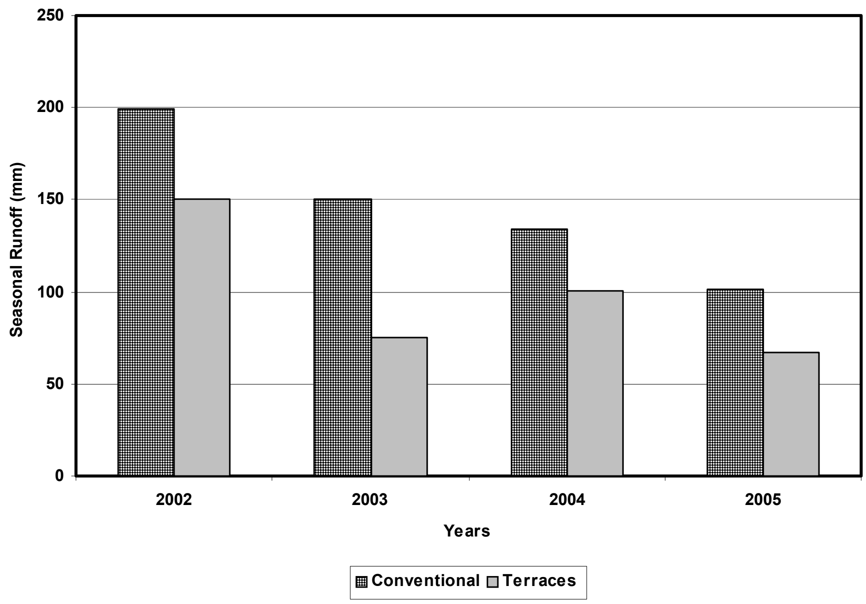

Figure 10. Runoff generation in conventional farming and terraces in Vidunda village.

Conclusions and Recommendations

Conclusion

Results showed that maize yields are high but not significantly different for different soil conservation measures (contour bunds, terraces and terraces with bunds) and in conservation tillage (e.g. Deep tillage 90 cm soil depth). On the other hand, it was found that low maize yield is associated with shallow soil depth, which is a consequence of continuous conventional farming on steep slopes without conservation measures. Therefore, low maize yield in Vidunda village is caused by the effect of soil depth rather than the conservation measures. The conservation measures are needed now because the soil is continuing eroding and with introduction of innovations such as stone terraces, some land with shallow depth might be reclaimed.

Recommendations

The PT model can be used to run several simulations for other villages or wards so as to determine optimal management practices to increase maize productivity for different locations. Also, the model could allow knowing and understanding the reasons why there are good or poor yields in an area.

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