Predicting rainwater harvesting potential in field-scale reservoir systems for supplemental irrigation to crops

Department of Agricultural and Biosystems Engineering

Pramod K Pandey[1*], Pieter van der Zaag[2*], Michelle L. Soupir[1], Vijay P. Singh[3], Sudhindra N. Panda[4]

[1*]Agricultural and Biosystems Engineering Department, Iowa State University, USA (pkpandey@iastate.edu); [2*]UNESCO-IHE Institute for Water Education, Delft, Netherlands, Water Resources Section, Delft University of Technology, Delft, Netherlands(p.vanderzaag@unesco-ihe.org); [3]Department of Biological and Agricultural Engineering, Texas A& M University, USA; [4]Agricultural & Food Engineering, Indian Institute of Technology, Kharagpur, India.

Introduction

By 2050, more than 59% of the world population will live in areas with limited water storage in rivers and aquifers [1]. When competing demands for freshwater exist, domestic and industrial uses will likely reduce the water available for agricultural purposes [2]. The World Bank's new water resources strategy emphasizes investments for increasing water storage structures [3]. Considering the monetary investments required, and adverse environmental impacts of constructing large reservoirs, on-farm reservoirs (OFR) could be a more viable option to meet agricultural water demands.

Objective

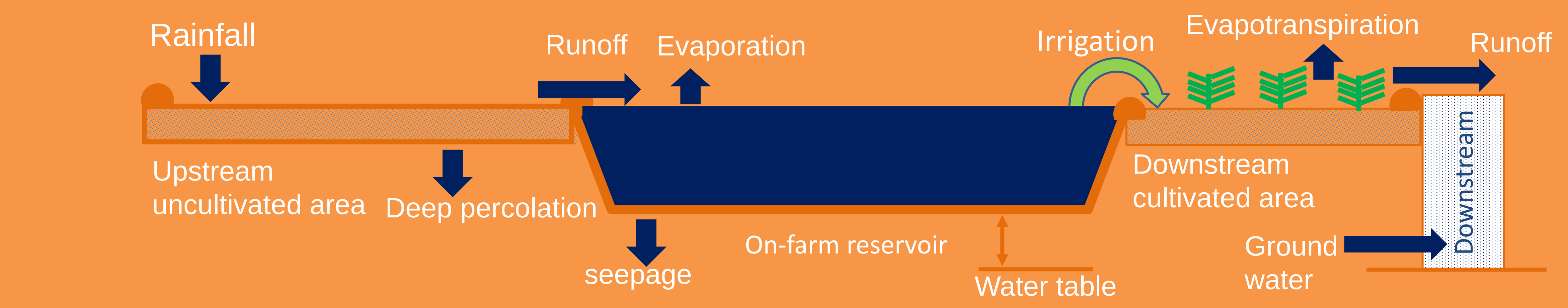
Develop a water balance model for estimating the water storage in on-farm reservoirs (OFR).

Method

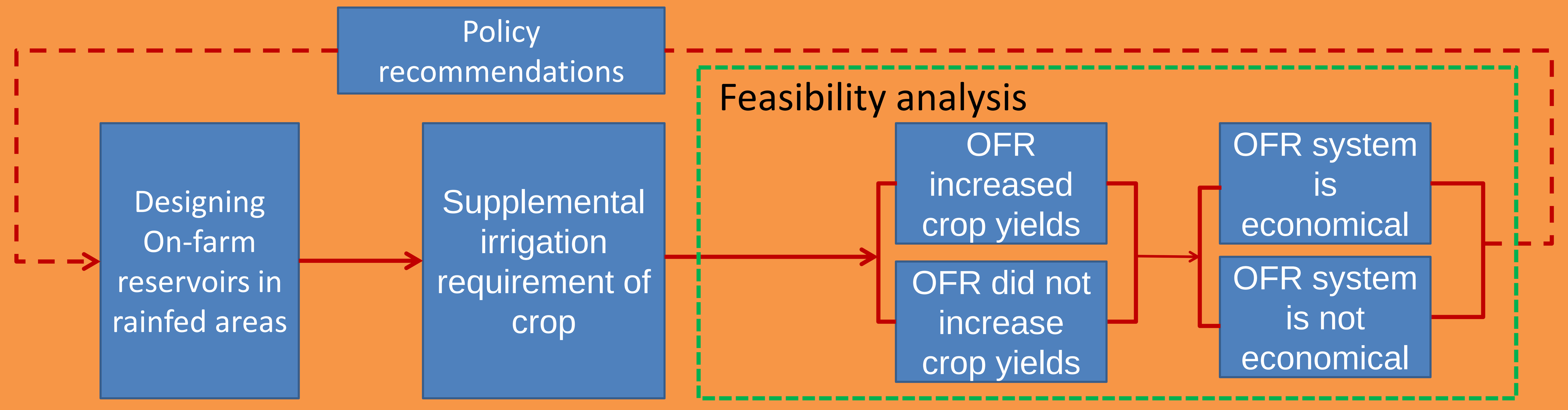
1. OFR water storage: $dv/dt = R - Q - E - S - SI$
2. Soil moisture: $ds/dt = P_{eff} - Q - ET_a - D + SI$
3. Supplemental irrigation: $SI = \min(SI_{max}, (WS_{OFR}/A_c))$

Symbols: dv/dt is change in OFR water storage; ds/dt is change in soil moisture; SI is supplemental irrigation applied; R is rainfall; Q is runoff; E is evaporation; S is seepage from OFR; P_{eff} is the effective precipitations; ET_a is actual evapotranspiration; D is deep percolations; SI_{max} is maximum allowed supplemental irrigation; WS_{OFR} is water storage; and A_c is crop land area.

Conceptual water flow



Project frame work



Experimental study results

To test the feasibility of OFR systems, eighteen field-scale OFRs were designed in India [4] in a rainfed area. Rain water harvested in the OFR was used for supplemental irrigation to rice and mustard crops, and for fish cultures in the OFR. Economic analysis of the OFR system has shown that the OFR can increase the farmer's income by increasing crop yields as well fish cultures (an extra source of food). the table shows the increased crop and fish yields in the OFR systems.

Systems	Rice	Mustard	Fish in the OFR
Rainfed	Yield 2650 kg/ha	Yield 600 kg/ha	NA
OFR	Yield 3740 kg/ha	Yield 660 kg/ha	Yield 755 kg/ha
Increase (%)	41.1	10	100
Benefit cost ratio = 1.28			


OFR designing

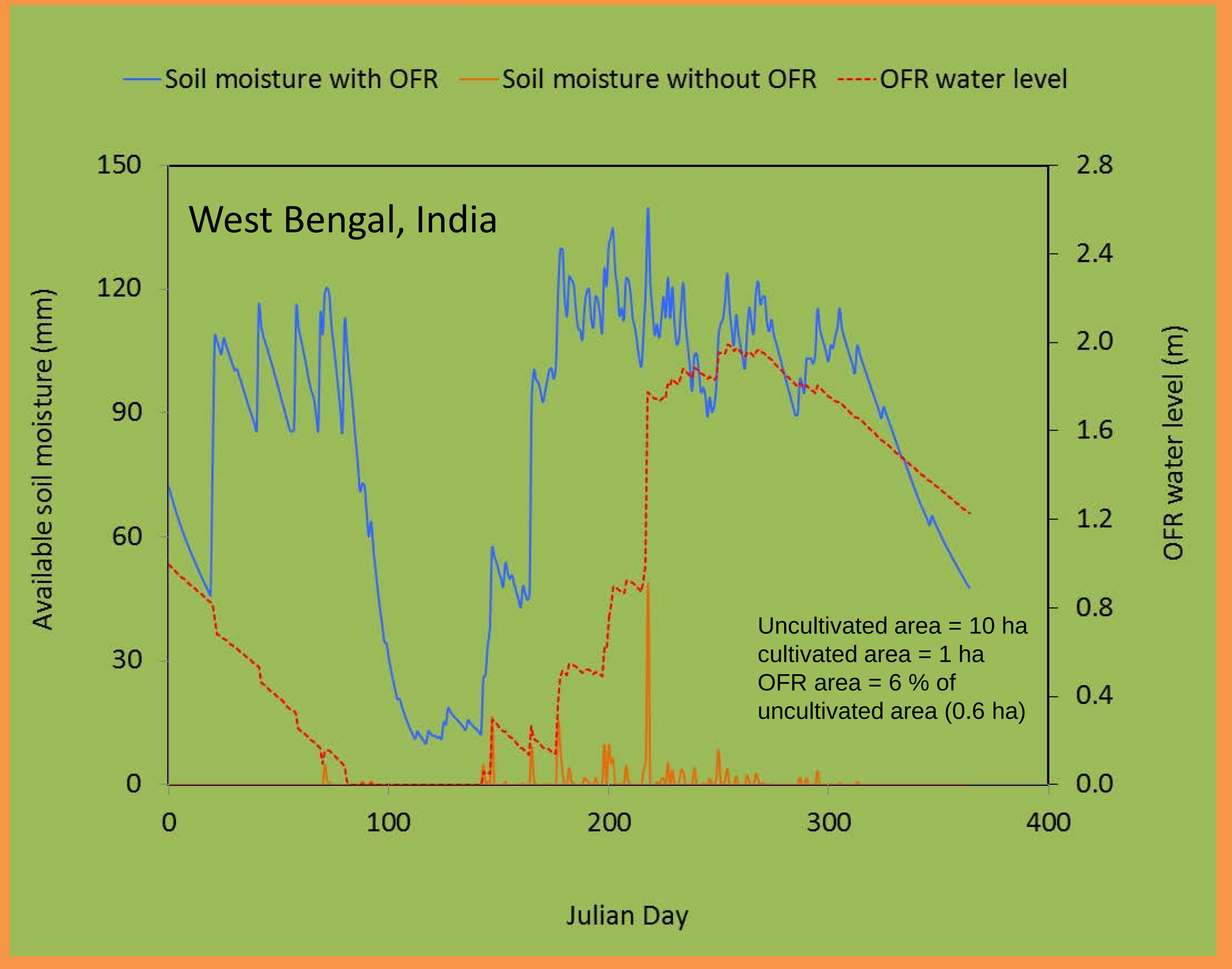

Fish harvesting from the OFR

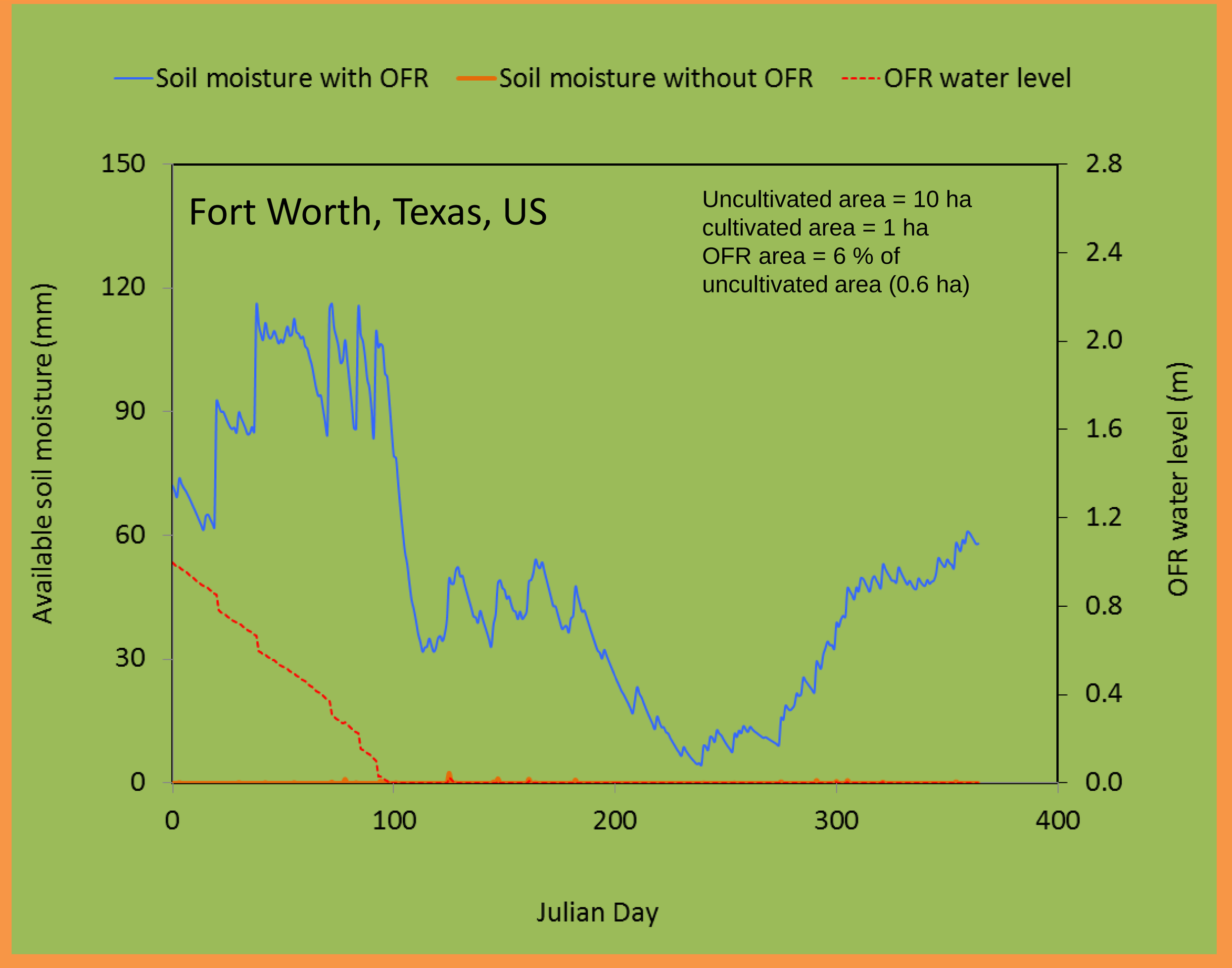

OFR water storage


Supplemental irrigation

Modeling results

Predicted soil moisture and OFR water level for India (left) and US (right)





Conclusions

1. For West Bengal, India, both experimental and prediction results have shown that converting rainfed land into an OFR system can increase the soil moisture of cultivated land by providing supplemental irrigation, and the OFR can potentially be used for fish cultures.
2. For Fort worth, Texas, U.S., results show that soil moisture of cultivated land can be increased in the OFR systems, however, water may not be available for fish cultures and multiple supplemental irrigations due to comparatively low rainfall.

Recommendations for future work

1. For Texas, US, field experiments for an OFR feasibility study would be useful to verify the model results.
2. The OFR systems will impact the hydrology at the watershed scale. The integration of this OFR model into a watershed scale model would be useful to predicting changes in hydrology at the watershed scale.
3. Further work is needed to determine the impacts of the OFR on downstream water quantity.

References: [1] Rockstrom J, Falkenmark M, Karlberg L, Hoff H, Rost S, Gerten D (2009) Future water availability for global food production: The potential of green water for increasing resilience to global change. Water Resources Research 45: W00A12. [2] van der Zaag P, Gupta J (2008) Scale issues in the governance of water storage projects. Water Resource Research 44: W10417. [3] World Bank (2010) Water Resources Sector Strategy: Strategic Directions for World Bank Engagement, Washington, DC, US. [4] Pandey PK, Panda SN, Panigrahi B (2006) Sizing on-farm reservoirs for crop-fish integration in rainfed farming systems in Eastern India. Biosystem Engineering 93: 475–489.