University of Natural Resources and Life Sciences, Vienna

Department of Water, Atmosphere and Environment

Institute of Hydraulics and Rural Water Management

Master Thesis

ON

# SOIL MOISTURE PREDICTION IN AN AGRICULTURAL FIELD OF GUMARA-MAKSEGNIT WATERSHED, NORTH GONDAR, ETHIOPIA

In Partial Fulfillment of

Master Degree

Submitted by

Muuz Gebretsadik **Gebremariam**

Vienna, 31 July, 2014

Supervisor: Ao.Univ.Prof. Dipl.-Ing. Dr.nat.techn. Andreas Klik

Co – supervisor: PhD, Ziadat Feras (ICARDA)

***Abstract***

*The master study on "Soil Moisture Prediction in an Agricultural Field of Gumara-Maksegnit Watershed" was conducted within Gumara-Maksegnit Watershed found in the Ethiopian highlands, North Gondar. This was aimed to predict moisture contained in 1meter soil profile spatially and temporally in the drying process of the 2013 wet period in small rainfed agricultural field mainly covered with cereal and legume crops. A Weekly soil moisture content (v/v) with PR2/6 Profile Probe which is product of Delta T Devices, topogrpaphic information with a spatial resolution of 5 by 5 meter measured using GPS and water level, soil texture in two soil depth ranges, crop information and representative soil bulk density were measured in the study period i.e. 30July 2013 to 9November 2013.*

*Soil moisture observation with a PR2 Profile probe, calibrated with gravimetric measured value, were characterized and analyzed using basic statistics for data quality and consistency along time and space. Reasonable but high temporal soil moisture variability was observed in the top 10 to 20 cm soil layer compared to the rest of layers down to 1meter.*

*Physically based hydrological model called Soil-Plant-Atmospher-Water (SPAW), developed by E. Saxon, 2006; was used to predict the temporal change of soil moisture considering the basic soil properties and agroclimatologic information together with crop data. Geostatistical analyst, Co-kriging in ArcGIS 10.2 (ESRI), was applied to predict the spatial distribution of soil moisture considering slope as a secondary variable and the temporally predicted soil moisture as the main variable. Results from both models were checked for their consistency using coefficient of determination (R2), root mean squared error and averaged standard error. $R^2$ value of observed versus SPAW simulated soil moisture in the period of drying process shows 0.72. Spatially distributed soil water storage (SWS) with Co-kriging produced average standard error of 12.8 with maximum and minimum SWS of 325mm/m and 246mm/m respectively.*

*Key words: Soil moisture, SPAW, co-kriging, spatial and temporal, drying process, soil water storage, slope, ArcGIS*

***Zusammenfassung***

*Im Rahmen der Masterarbeit "Soil Moisture Prediction in an Agricultural Field of Gumara-Maksegnit Watershed" wurden Bodenmessungen im Gumara-Maksegnit Einzugsgebiet (Nord-Gondar, Äthiopien) durchgeführt. Ziel der Arbeit ist die Abschätzung der räumlichen und zeitlichen Verteilung der Bodenfeuchte während der Trockenperiode für die Bodenschicht bis 1 m Tiefe. Hierfür wurde wöchentlich die Bodenfeuchte mittels PR2/6 Profile Probe gemessen. Zusätzlich wurde die Topographie mit einer Auflösung von 5 m aufgenommen sowie Wasserstände, Bodentextur, Bewuchs und Lagerungsdichte während des Beobachtungszeitraumes (30. Juli 2013 bis 09. November 2013) aufgenommen.*

*Bodenfeuchtemessungen wurden statistisch ausgewertet und kalibriert. Die Messungen zeigten eine hohe Variabilität der Bodenfeuchte für die oberste 10 – 20 cm im Vergleich zu tieferen Bodenschichten mit geringeren Schwankungen. Die mittlere Wasserspeicherkapazität wurde bestimmt und zeigte steigende Variationskoeffizienten im Verlauf des Trocknungsprozesses.*

*Zur Abschätzung der zeitlichen VEränderung der Bodenfeuchte unter Berücksichtigung bodenphysikalischer Eigenschaften, Bewirtschaftung und klimatischer Randbedingungen wurde das physikalisch-basierte Model „Soil-Plant-Atmosphere-Water"(SPAW) verwendet. Zusätzliche wurde die räumliche Verteilung mittels Interpolation Co-Kriging geschätzt. Die Ergebnisse beider Methoden wurden mit Beobachtung verglichen. Das SPAW Model zeigte $R^2$ Werte von 0.72. Co-Kriging führt zu einem mittleren Fehler von 12.8 mm/m, mit Minimal- und Maximalwerten von 246 mm/m und 325 mm/m.*

***Acknowledgments***

I would like to gratefully acknowledge the great support from my advisor, Ao. Univ, Prof. Andreas Klik, and my co-advisor, Feras Ziadat. Your patience and understanding were very much appreciated.

I express my deep gratitude to my wife Mebrhit Gebreyohanes and my son Robel Muuz for their sacrifice during my stay in Vienna.

Extra and special thanks goes to the “Unlocking the potential of rain-fed agriculture in Ethiopia for improved rural livelihood” Project team members and also the project partners, ICARDA, ARARI and BOKU University of Natural Resources and Life Sciences all funded with ADA, for their financial help to conduct my full master study in Vienna, Ethiopia. The same thanks go to IFAD funded project conducted in the same research area.

Lots of love goes out to my parents for everything they have done and continuous pray for my successes.

Many thanks goes to Boku University students; Claire, Stefan, Florian, Cristoph and Ingrid for their best friendship and technical helps towards me during my stay in Vienna, Austria.

**Content** **page**

**List of Figures**

## List of Tables

# List of Acronyms and Symbols

| | |
|---|---|
| ADA | Austrian Development Agency |
| cm | Centimeter |
| CRLE | Complementary Relationship Lake Evaporation |
| CSV | Comma separated values |
| ETP | Evapo-transpiration Potential |
| ETo | Reference crop evapotranspiration |
| FAO | Food and Agricultural Organization |
| FB | Faba Bean |
| FSU | Former Soviet Union |
| IAEA | International Atomic Energy Agency |
| ICARDA | International Center for Agricultural Research in the Dry Areas |
| IFAD | Internationa Fund for Agricltural Devellopment |
| Inter.quar. | inter quartile |
| ITCZ | Tropical Convergence Zone |
| h | hour |
| ha | hectare |
| ISO | Iterative Self Organizing |
| $km^3$ | kilo meter cubic |
| Km | Kilometer |
| Kpa | kilo pascal |
| masl | meter above sea level |
| min | minute |
| mm | millimeter |
| mm/m | millimeter of water per meter soil profile |
| MSE | Mean Squared Error |
| $MW/m^2$ | Mega Wat per square meter |
| m/s | meter per second |
| NSE | Nash Suitcliff Efficiency |
| Oct | October |
| P | Predicted |
| r | Correlation coefficient |
| RETC | Retention curve |
| RMSE | Root Mean Squared Error |
| $R^2$ | Coefficient of determination |
| Sep | September |
| SPAW | Soil Plant Atmosphere Water |
| Sorg | Sorghum |
| SSE | Sum of Squared Error |
| StDev | Standard deviation |
| SWS | Soil Water Storage (SMS) Soil Moisture |
| SWC | Soil Water Content |
| Temp. | Temperature |
| TIN | Triangulated Irregular Network |
| USDA | United States Department of Agriculture |
| USA | United States of America |

| | |
|---|---|
| v/v | Volume per Volume |
| WC | Water Content |
| WAVES | (Water, Atmosphere, Vegetation, Energy, Solute) |
| $^{o}c$ | Degree centigrade |
| % | Percent |
| @ | at |
| $\theta_{rel}$ | Relative water content |
| $\theta_{fc,}$ | Water content at field capacity |
| $\theta_{pwp,}$ | Water content at permanent wilting point |
| Rn | Net radation |
| G | Soil heat flux density |
| T | Air temperature |
| U2 | Wind speed |
| es | Saturation vapour pressure |
| ea | Actual vapour pressure |
| y | Psychrometric constant |
| $\beta$ | Bowen ratio |
| $\Delta$ | Slope of the saturated vapour pressure-temperature curve |