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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
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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, topographic 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 (R^2), 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. Zusätzlich 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.

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List of Acronyms and Symbols

ADA	Austrian Development Agency
cm	Centimeter
CRLE	Complementary Relationship Lake Evaporation
CSV	Comma separated values
ETP	Evapo-transpiration Potential
ET _o	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	International Fund for Agricultural Development
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)
°C	Degree centigrade
%	Percent
@	at
θ_{rel}	Relative water content
θ_{fc} ,	Water content at field capacity
θ_{pwp} ,	Water content at permanent wilting point
Rn	Net radiation
G	Soil heat flux density
T	Air temperature
U2	Wind speed
es	Saturation vapour pressure
ea	Actual vapour pressure
y	Psychrometric constant
β	Bowen ratio
Δ	Slope of the saturated vapour pressure-temperature curve