Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 15	No. 3	pp. 1077-1082	2016

Original Research Paper

Predicting Sediment Load and Runoff in Geo WEPP Environment from Langat Sub Basin, Malaysia

Mohammad Zahirul Haque*(****), SahibinAbd Rahim*†, Md. Pauzi Abdullah*, Ahmad Fuad Embi*****, Rahmah Elfithri**, Tukimat Lihan* and Mazlin Mokhtar****

*School of Environmental and Natural Resources Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

**Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

***School of Chemical Sciences and Food Technology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

****Bangladesh Forest Department, Bono Bhaban, Agargaon, Dhaka 1207, Bangladesh

*****Department of Hydrology, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

†Corresponding author: SahibinAbd Rahim

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 11-11-2015
Accepted: 10-12-2015

Key Words:
WEPP interface
Flow accumulation
TOPAZ algorithm
Sediment load

ABSTRACT

This study monitors and predicts the sediment load and runoff at the UKM catchment - the Langat sub basin of Peninsular Malaysia using the WEPP software interfaced in ArcGIS 10.2. Within Geo WEPP and WEPP interfaces, TOPAZ algorithm and climate generator (CLIGEN) were used to parameterize the aspects of land cover, slope, climate, soil and topographic data and estimate stochastic climatic parameters respectively. Range of soil parameters was defined by utilizing soil properties such as frequency of soil particles, CEC and OC. The management factor was generated applying EPIC algorithm for land use types during the simulation period 2000 to 2014. The study shows that variation occurs between sediment prediction by GeoWEPP and the measured value of the same. The findings provide further the useful information about the measuring technique and status of the sediment load and runoff for the soil erosion management. This study suggests the longer span of monitoring as part of the comprehensive management plan is needed for the Langat River Basin.

INTRODUCTION

Soil erosion and its related impacts can create complex threats to the environment. Quantification of soil loss is one of the greatest challenges in natural resources and environmental planning (Pimentel et al. 1995, Bhuyan et al. 2002). Soil loss processes are important to understand for effective management. GIS-based spatial modelling has been introduced to soil erosion prediction and consequently in the development of appropriate soil conservation strategies especially at the upstream basin (Jain et al. 2005, Memarian et al. 2013).

Water erosion prediction project (WEPP) plays an increasingly critical role in conservation and assessment efforts (Flanagan et al. 2001). It is a spatially distributed and process-based continuous simulation erosion model that allows to capture the terrain indices such as stream power index, wetness index, sediment transport capacity index and erosion hazard index in three-dimension (Cochrane & Flanagan 1999). WEPP model is applied to assume soil erosion and sedimentation at the catchment scale (Dun et al. 2009). GeoWEPP is a geo-spatial erosion prediction model interfaced in ArcGIS. Integration of WEPP with a Geographic Information System is appreciated because it facilitate sand improve model application. GIS tool functions as a geo-spatial tool to assemble, process, analyse, and visualize the environmental data. It connects between the user's scale of interest and the scales related to available process data and models. The GeoWEPP approach illustrates that it is critical to develop a scientific and functional framework for the design, implementation, and use of such geo-spatial model assessment tools. The way that GeoWEPP was developed and implemented suggests a framework and scaling theory leading to a practical approach for developing geo-spatial interfaces for process models. GeoWEPP accounts for fundamental water erosion processes, model, and users' needs, but most importantly, it also matches realistic data availability and environmental settings by enabling even non-GIS-literate users to assemble the available geo-spatial data

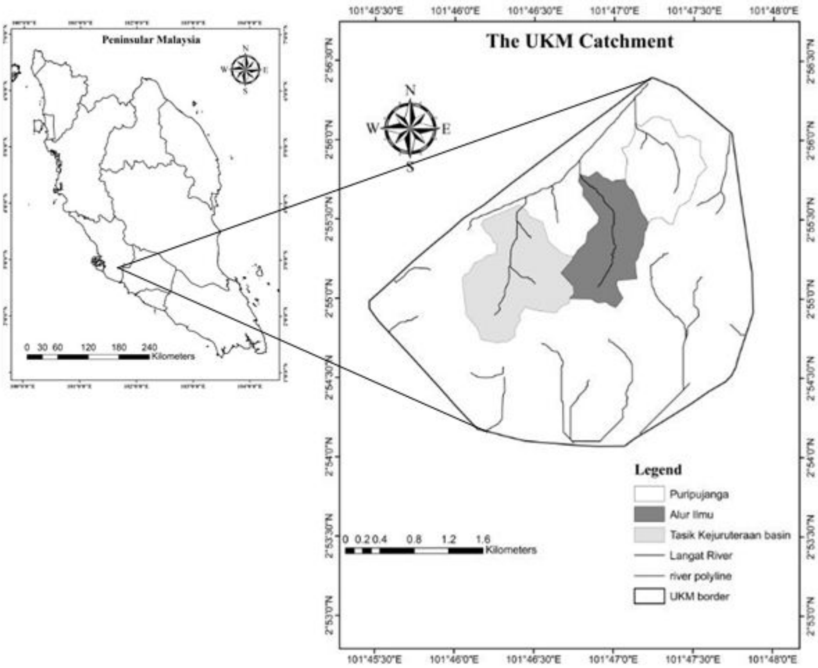

Fig. 1: Geographic location of the UKM Catchment.

quickly to start soil and water conservation planning (Renschler 2003). The manual generation of input data and its application in small water sheds is a limitation of WEPP but overcomes by GeoWEPP.

This study was carried out with the aim of monitoring and prediction of the sediment load and runoff at the UKM catchment-the Langat sub basin of Peninsular Malaysia using the WEPP software interfaced in ArcGIS.

MATERIALS AND METHODS

Study area: The UKM (Universiti Kebangsaan Malaysia) catchment is situated on the upstream as well as at the east margin of the Langat River in the district of Bangi under the Selangor state of Peninsular Malaysia. The watershed covers the drainage area of 12.38 km^2. Three significant tributaries namely Tasik Kejuruteraan, Alur Ilmu and Puripujanga are situated in the catchment with the lengths of these tributaries as 1596.60 m, 2098.75 m and 1770.20 m respectively. Geographically, it is bounded by 2°55'22" to 2°55'30" N latitudes and 101°46'18" to 101°46'23" E longitudes (Fig.1). Minimum and maximum altitudes of the basin are 20 and 108 m while the mean is the 56±19 m above the mean sea level. The lowest and highest slopes are 0 and 74.66%, respectively (Fig. 2). The average annual precipitation recorded from the UKM rain station is 2197.20 mm. The land use of UKM catchment comprises of crop land 12.90%, forest land 38.49%, grassland 10.89%, mangroves 0.29%, wetlands 1.66%, settlements 34.74% and others 1.04%. The average sediment loaded in the water from the basin is approximately 3600 tons per year.

WEPP and GeoWEPP modelling: To predict sediment load at the watershed scale, Agriculture Research Service, Purdue University, and the USDA National Soil Erosion Research Laboratory developed GeoWEPP that acts as a combined project (Minkowski & Programmer 2010). This interface integrates WEPP model and TOPAZ (topography parameterization) algorithm within ArcGIS software.

The runoff between rill and inter-rill regions can be separated by WEPP. The soil erosion is calculated separately in these regions. Steady state sediment continuity equation is used to predict the quantum of rill and inter-rill erosion. Rill erosion occurs when shear stress of flow exceeds critical shear stress and the sediment load in water flow is less than the transport capacity. WEPP shows that the inter-rill erosion is proportional to the square of the rainfall intensity (Nearing et al. 1989). Sediment load occurs from the inter rill region and then gets delivered to rills. The model computes normalized sediment load using non-dimensional detachment and deposition equations. The normalized load is then converted into actual load (Aksoy & Kavvas 2005).

Input files such as land cover, slope, climate, soil and management of the UKM catchment were generated within

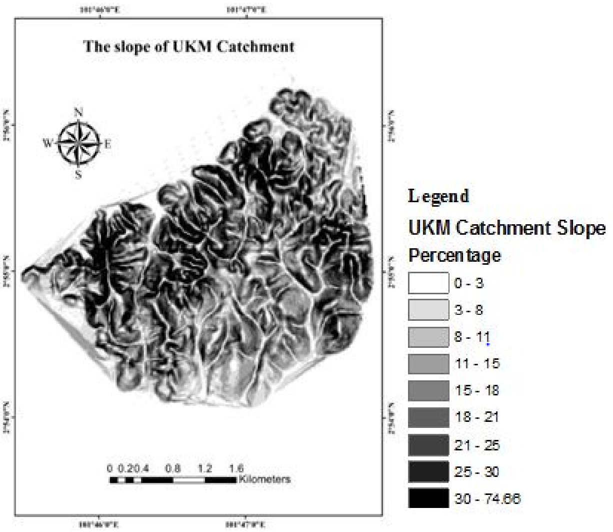

Fig. 2: Slope map of the UKM Catchment.

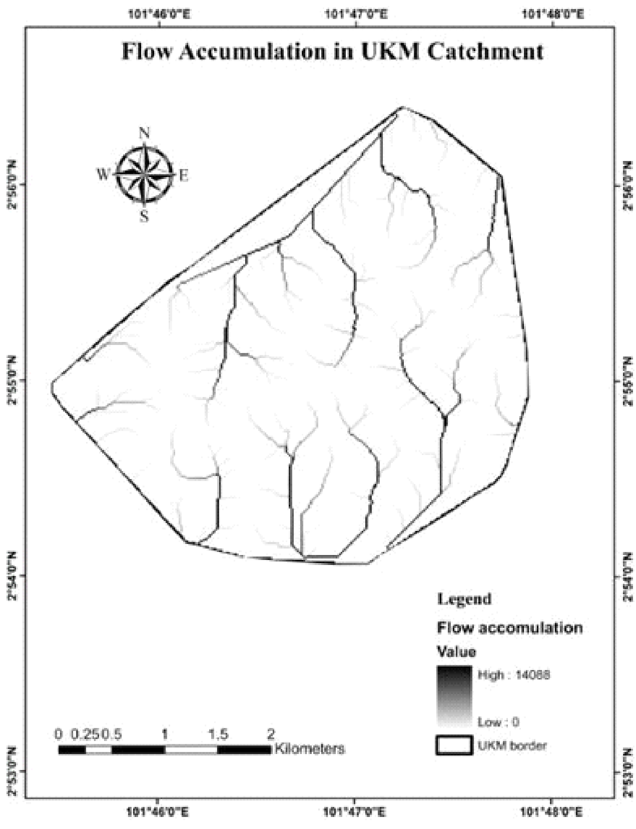

Fig. 3: Flow accumulation map of the UKM Catchment.

GeoWEPP interface, while the topographical data in the form of digital elevation model (DEM) of the catchment slopes were parameterized using TOPAZ algorithm.

Channel network was adjusted by manipulating the values of Mean Source Channel Length (MSCL) and Critical Source Area (CSA). The MSCL and CSA are termed for the shortest channel length and the minimum drainage area respectively (Garbrecht & Martz 1997). Flow accumulation map was prepared in ArcGIS 10.2 as the base map to extract the above parameters (Fig. 3).

Daily values of precipitation, temperature, solar radiation, relative humidity and wind speed were obtained from the meteorological station situated at the department of Geography, UKM, Selangor for the period of 2000 to 2014 and were input into CLIGEN algorithm to estimate the stochastic climatic parameters.

The UKM catchment consists of three soil series, which are Telemong-Akob-Localalluvium, Munchong-Seremban and Rengam-Jerangau soil series (Fig. 4). The important physicochemical soil parameters such as texture albedo, saturation level, and hydraulic conductivity for calculating rill and inter-rill erodibility level and critical shear stress are given in Table 1.

A management file was generated using Environmental Policy Integrated Climate (EPIC) algorithm for different land use types. The land use in UKM catchment is comprised of crop land, forest land, grassland, mangroves, wetlands, settlements and other uses during the simulation period 2011 (Fig. 5). WEPP generated inter-rill cover data for each year using growth parameters, soil and climatic data.

RESULTS AND DISCUSSION

Monthly sediment load and runoff value was measured at the outlets of Tasik Kejuruteraan, Alur Ilmu and Puripujang tributaries (Fig. 6). The result showed that measured sediment load was 2.91 $ha^{-1}yr^{-1}$ and the measured daily runoff value averaged on a monthly basis was 2.58 mm/day. Monthly simulated value of sediment load and runoff from GeoWEPP was compared to monthly measured value of the same. From GeoWEPP, the predicted value for sediment load was 5.76 $ha^{-1}yr^{+}$, approximately 2 times more than the measured value, and the simulated value for runoff was 2.16 mm/day. Student t-test at 99% confidence level showed a significant difference between simulated and measured sediment load. Correlation between predicted and measured sediment load was 0.525 indicating that WEPP model overestimates sediment load. Similar results were reported for WEPP application in the Lui watershed. However, in the agricultural crop, the observed and WEPP predicted erosion for single storm events were found fairly correlated (r= 0.77) (Zhang et al. 1996). This states the better predictive ability of WEPP. In another study, Martínez de Anguita et al. (2011) showed that observed and WEPP predicted sediment loads in a non-

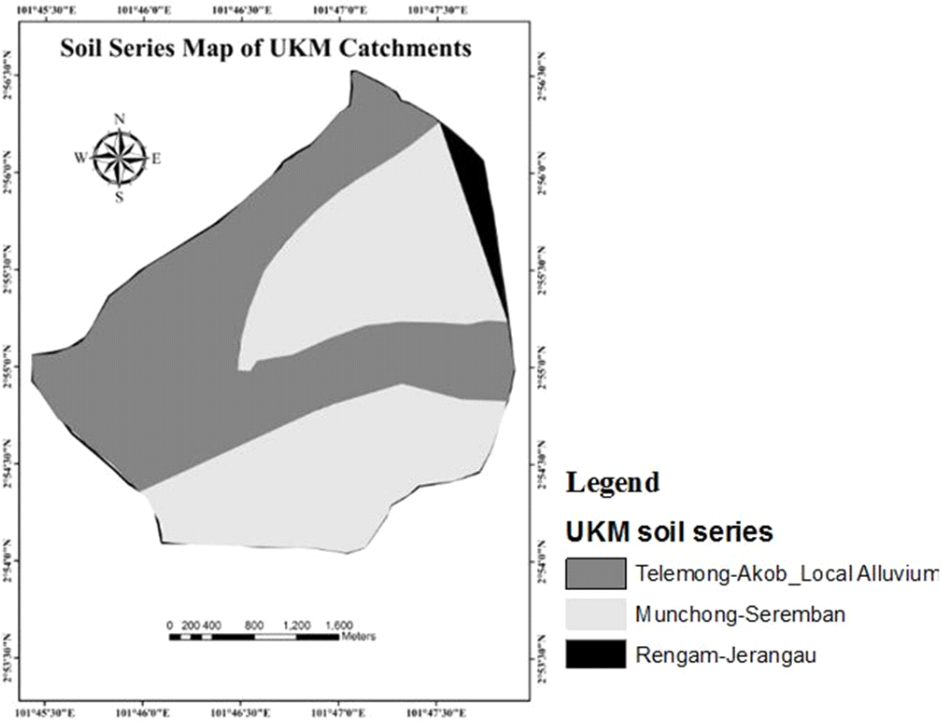

Fig. 4: Soil Series map of the UKM catchment.

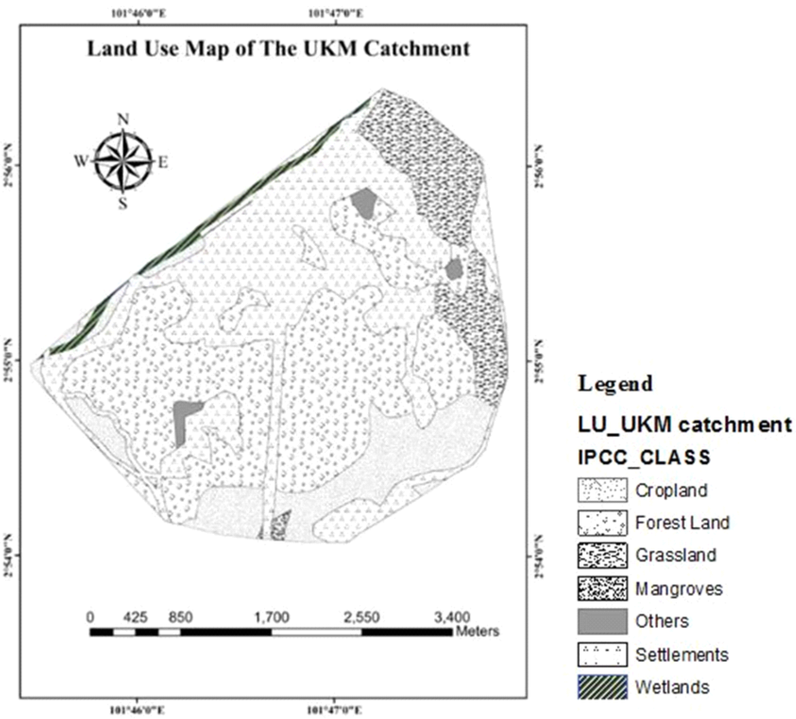

Fig. 5: Land use map of the UKM Catchment.

Table 1: Soil physico-chemical properties of three soil series.

Soil Series	Depth (cm)	Particles (%)				CEC	OC
		Clay	Silt	Fine Sand	Course Sand	(m.e./100gsoil)	
Telemong-Akob- Local Alluvium	15	54	34	6	6	19.67	3.3
Munchong- Seremban	15	49	8	31	12	13.98	1.3
RengamJerangau	15	31	7	42	20	6.88	1.2

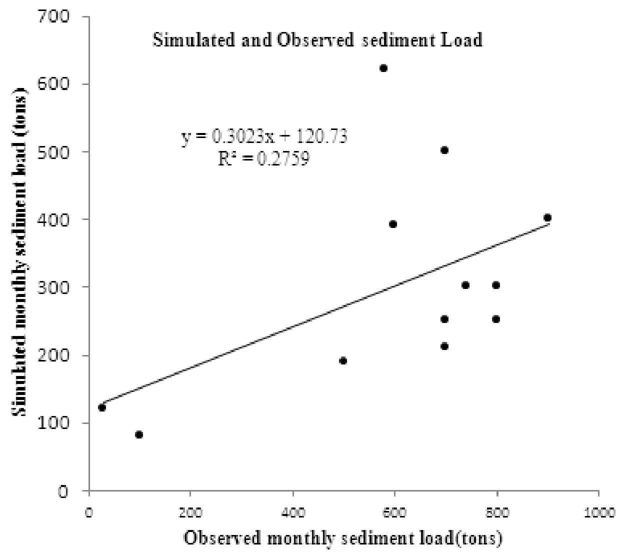

Fig. 6: Measured sediment load versus predicted sediment load.

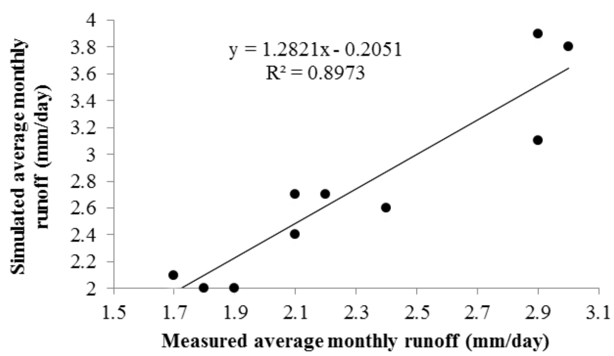

Fig. 7: Measured runoff height versus predicted runoff height.

harvested forest were highly correlated (r = 0.8). Moreover, the average of monthly runoff prediction in GeoWEPP and measured runoff were found strongly correlated (r = 0.947) (Fig. 7), though in this case, several WEPP-predicted values were less than the measured values. The study uses the rainfall data that was collected from only one gauge station but in general the tropical watershed has high spatial variation of rainfall, (Memarian et al. 2013). The reasons for less value of runoff in GeoWEPP prediction may be attributed to this finding.

TheUKM catchment is subjected to anthropogenic manipulations in hydrological status. Some land forms such as ditch, or ground holes resulting from urban development were not included in the land use and therefore these are unavailable in topography maps. These unmentioned feature scan affect the sedimentation process through variation in sediment deposition rate (Memarian et al. 2012).

CONCLUSION

The study finds that the GeoWEPP over estimates sediment load and under estimates runoff value in comparison with measured value for both the aspects. The correlation analysis and model reveals that GeoWEPP predicts runoff more accurately than sediment load.

However, there are a number of possible criticisms of the WEPP model. Among those, the large computational and data requirements of the model may limit its applicability in catchments where there is often few data or available resources. Many of the model parameters may need to be calibrated against observed data in such studies, creating problems with model identification ability and the physical interpretability of model parameters. Also the rill and inter-rill erosion estimated by WEPP may not be applicable in cultivated soils that initially do not exhibit rill formations.

ACKNOWLEDGEMENT

The university research projects- LIV-2014-04; PIP-2013-004 and AP 2014-010 of Universiti Kebangsaan Malaysia (UKM) is gratefully acknowledged for supporting this research.

REFERENCES

Aksoy, H. and Kavvas, M. L. 2005. A review of hillslope and watershed scale erosion and sediment transport models. Catena, 64: 247-271.

Bhuyan , S. J., Kalita, P. K., Janssen, K. A. and Barnes, P. L. 2002. Soil loss predictions with three erosion simulation models. Environ. Model. & Soft., 17: 135-144.

Cochrane, T. and Flanagan, D. 1999. Assessing water erosion in small watersheds using WEPP with GIS and digital elevation models. J. Soil Water Conserv., 54: 678-685.

Dun, S., Wu, J. Q., Elliot, W. J., Robichaud, P. R., Flanagan, D. C., Frankenberger, J. R., Brown, R. E. and Xu, A. C. 2009. Adapting the water erosion prediction project (WEPP) model for forest applications. J. Hydro., 366: 46-54.

Balasundram, S., Talib, J., Anuar, A. and Memarian, H. 2011. Accuracy of GeoWEPP in estimating sediment load and runoff from a tropical watershed. M'sian J. Soil Sci., 15: 25-33.

Flanagan, D. C., Ascough, II, J. C., Nearing, M. A. and Laflen, J. M. 2001. The water erosion prediction project (WEPP) model. Landsc. Eros. and Evol. Model, Springer.

Garbrecht, J. and Martz, L. 1997. TOPAZ Topographic Parameterization Software. USDA Agri. Res. Serv. Grazinglands Res. Lab., El Reno, OK.

Jain, M. K., Kothyari, U. C. and Raju, K. G. 2005. GIS based distributed model for soil erosion and rate of sediment outflow from catchments. J. Hydraulic Eng., 131: 755-769.

Martínez De Anguita, P., Rivera, S., Beneitez, J. M., Cruz, F. and Espinal, F. M. 2011. A GIS cost-benefit analysis-based methodology to establish a payment for environmental services system in watersheds: application to the Calan River in Honduras. J. Sustain. Fores., 30: 79-110.

Memarian, H., Balasundram, S. K., Talib, J. B., Teh Boon Sung, C., Mohd Sood, A. and Abbaspour, K. C. 2013. KINEROS2 application for land use/cover change impact analysis at the Hulu Langat Basin, Malaysia. Water Environ. J., 27: 549-560.

Minkowski, M. and Programmer Lead GeoWEPP 2010. Advanced GeoWEPP Tools. Creation and Use of Four Text Files Linked to Landuse and Soils Layers within GeoWEPP.

Nearing, M., Foster, G., Lane, L. and Finkner, S. 1989. Erosion prediction project pechnology. Transactions of the ASAE, 32(5): 1587-1593.

Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., Mcnair, M., Crist, S., Shpritz, L., Fitton, L. And Saffouri, R. 1995. Environmental and economic costs of soil erosion and conservation benefits. Sci. AAAS-Weekly Paper Edit., 267: 1117-1122.

Renschler, C. S. 2003. Designing geo-spatial interfaces to scale process models: the GeoWEPP approach. Hydrol. Process., 17: 1005-1017.

Zhang, L., O'neill, A. L. and Lacey, S. 1996. Modelling approaches to the prediction of soil erosion in catchments. Environ. Soft., 11: 123-133.