Nigerian Journal of Technology (NIJOTECH)
Vol. 32. No. 2. July 2013, pp. 197-202

University of Nigeria, Nsukka, ISSN 1115-8443
www.nijotech.com

SOIL LOSS IN SAMARU ZARIA NIGERIA: A COMPARISON OF WEPP AND EUROSEM MODELS

I. N. Obeta+, J. K. Adewumi*
+DEPARTMENT OF CIVIL ENGINEERING, UNIVERSITY OF NIGERIA, NSUKKA, ENUGU STATE, NIGERIA
*DEPARTMENT OF AGRIC ENGINEERING, AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA
E-mail: obetaifeanyi@gmail.com

Abstract
Soil erosion data generated while estimating soil loss in Samaru, Zaria using the EUROSEM model were used as input parameters for the prediction of soil loss in the same catchment area using the WEPP erosion model. A comparative analysis of both models for soil loss prediction showed that WEPP performed better for bare and cultivated soils for which there was a continuous trend of increase in soil loss with advancement of years which was also in agreement with the observed values.

Keywords: Comparative analysis, Soil loss, Overland flow, WEPP Model, EUROSEM Model

1. Introduction

Soil erosion by overland flow is a major ecological problem facing Nigeria and many parts of the world which are subject to heavy rainfall and as such Samaru, Zaria is not exempted [1-3]. The loss of nutrient-rich topsoil from hill slopes causes severe agricultural problems for an extremely vulnerable agricultural society that depends on soil quality as a fundamental base for its livelihood. This removal of soil in source areas leads to sediment accumulation in sink areas such as dammed reservoirs [4]

In recent times, the evaluation of soil erosion which is multidisciplinary in nature is being achieved by the use of soil erosion models. These models assist in the understanding of a given system and therefore when used for hypothesis testing can provide a predictive tool for management [5]. They are also useful in the design of erosion-control measures and the evaluation of land-use management practices [6]. The choice of which model to use depends therefore on the objective and scale of work to be done, the availability of data and support facilities.

A number of empirically and physically based soil erosion models have been developed. They include but are not limited to MEDRUSH (a product of the Mediterranean desertification and land use Project), Revised universal soil loss equation (RUSLE), European soil erosion model (EUROSEM), Agricultural non point source pollution model (ANGPS) and Water erosion prediction project model (WEPP). These have been described by various researchers [7-12].

The water erosion prediction project (WEPP) model is based on various interacting natural processes in hydrology, plant sciences, cropping, management, sediment detachment and deposition [13]. It was developed by the United States Department of Agriculture (USDA) as a replacement for empirically based erosion prediction technologies. It models soil loss by adding the sediment loss from the interrill area to the rill erosion. Soil loss is dependent on detachment capacity by rill flow and sediment transport capacity. It is based on a two dimensional hill slope profile approach and is able to predict deposition, erosion and sediment delivery along the profile and in small watersheds with its watershed aspect having the capability to incorporate free and impounded channels. It is a physically based continuous simulation model with climate predictions generated using the climate generator (CLIGEN) module.

Its erosion component is based on the continuity equation shown below:

$$\frac{dG}{dx} = Dr + Di \qquad (1)$$

Where,

G= sediment load ($kg \cdot s^{-1} \cdot m^{-1}$)

x = distance down slope (m)

Dr = rill erosion rate (+ for detachment, - for deposition)

Di = interrill sediment delivery ($kg \cdot s^{-1} \cdot m^{-2}$).

The European Soil Erosion Model (EUROSEM) was however developed in the United Kingdom for use in the countries of the European Community [14]. It is a single rainfall- event and dynamic distributed model that can be applied to (structured) slopes and small catchments (max. 50 ha) [15]. It is able to simulate sediment transport, erosion and deposition over the land surface by rill and interill processes in single storms for both individual fields and small catchments. The inputs of the model are topography, soil, vegetation, and rainfall parameters while the output includes total runoff, total soil loss, the storm hydrograph and storm sediment graph. Compared with other erosion models, EUROSEM has explicit simulation of interill and rill flow; plant cover effects on interception and rainfall energy; rock fragment (stoniness) effects on infiltration, flow velocity and splash erosion; and changes in the shape and size of rill channels as a result of erosion and deposition. The computation of soil loss is based on a numerical solution of the dynamic mass balance equation shown below:

$$\frac{\partial(AC)}{\partial t} + \frac{\partial(QC)}{\partial x} - e(x,t) = q_s(x, \qquad (2)$$

Where

C=sediment concentration m^3 A=cross-sectional area of the flow (m^2), Q=discharge ($m^{-3}s^{-1}$), q_s=external input or extraction of sediment per unit length of flow ($m^{-3}s^{-1}m^{-1}$), e=net detachment rate or rate of erosion of the bed per unit length of flow ($m^{-3}s^{-1}m^{-1}$), x=horizontal distance (m), and t=time (s).

A useful method to evaluate the effectiveness of soil-erosion models is to therefore compare the models' soil-loss estimates with measured data from experimental plots subjected to natural or simulated rainfall.

2. Description of study area

The experimental site as described by [1] is located at Ahmadu Bello University farm, Samaru near Shika on Zaria- Sokoto highway, which lies on longitude $07^o38^{'}$ E and latitude $11^o11^{'}$ N within the Northern Guinea Savannah zone of Nigeria. The annual rainfall amount ranges from 608mm to 1482mm with a mean of 1063mm. The highest rainfall is normally expected in August. The four experimental plots (A, B, C & D) each 6m×4m was cited on a clayey loam soil of the "Alfisols Series", as defined in [16]. In the FAO–UNESCO system [17], the soils are classified as "Nitosols" and "Luvisols." Plots A and B were weeded continuously to constitute the bare soil plots. Plot C had grasses to constitute the vegetated soil and plot D cultivated (ridged) and planted with maize. Table 1.0 shows further characteristic of soils in Samaru.

3. Method of analysis

The data analysis using the WEPP model was done on the WEPP software which runs on Microsoft windows operating system. The input parameters includes but are not limited to the soil slopes for the bare, cultivated and vegetated soil types, average annual rainfall intensity and soil type. The equation employed for soil loss estimation is as described in equation (1). The prediction results obtained were then compared with that previously obtained in [1] using EUROSEM whose equation for soil loss in described in equation (2) and that observed in the field.

Table 1.0: characteristics of soil in Northern Guinea Savannah: Samaru, Zaria, Nigeria

Soil Characteristics	Soil depth (cm)			
	0-17	17-31	31-82	>82
pH (H_2O)	5.2	4.9	5.4	5.3
Bulk density (mg/m^3)	1.39	1.47	1.45	1.67
Water retention at -0.01MPa (gKg^{-1})	310	359	343	344
Water retention at -1.5MPa (gKg^{-1})	61	147	206	253
Sand (gKg^{-1})	44	36	29	36
Clay (gKg^{-1})	15	28	38	35

Source: Oikeh et al [18].

Finally, a fundamental assumption which was used in the collection of field data on soil loss which served as a basis for comparing the model predictions was that "the sediment surface is very flat, perfectly homogeneous with respect to splash and isotropic in any direction since rainfall is vertical". It was also assumed that rainfall was "homogeneously distributed over the entire area of the experimental site where the splash-tray of 23cm×20cm was installed" [1].

4. Results and discussion

- Soil loss simulated by WEPP and that simulated by EUROSEM [1] were compared with observed soil loss over a three year period. From fig 1, it can be seen that the trend of progressive increase in observed soil loss for 1993-1995 and 1995-1996 were maintained by WEPP but that was not the case with EUROSEM as its 1996 predicted soil loss was lower than the previous years.
- Fig 2 shows that EUROSEM highly over predicted soil loss for 1993 and 1995 while WEPP showed under prediction for 1993 and 1996. This over prediction of relatively small measured soil loss values has been attributed not to a bias in the model predictions as a function of treatment, but rather to limitations in representing the random component of the measured data within treatments (i.e., between replicates) using a deterministic model [19].
- The trend of continued increase in soil loss with years was maintained by both WEPP and EUROSEM in fig 3 although WEPP had a more economical estimate.
- A further observation is that the vegetated soil showed the least soil loss. This is as a result of the vegetative cover that gives the soil a level of protection by the reduction of the erosivity of rainfall.

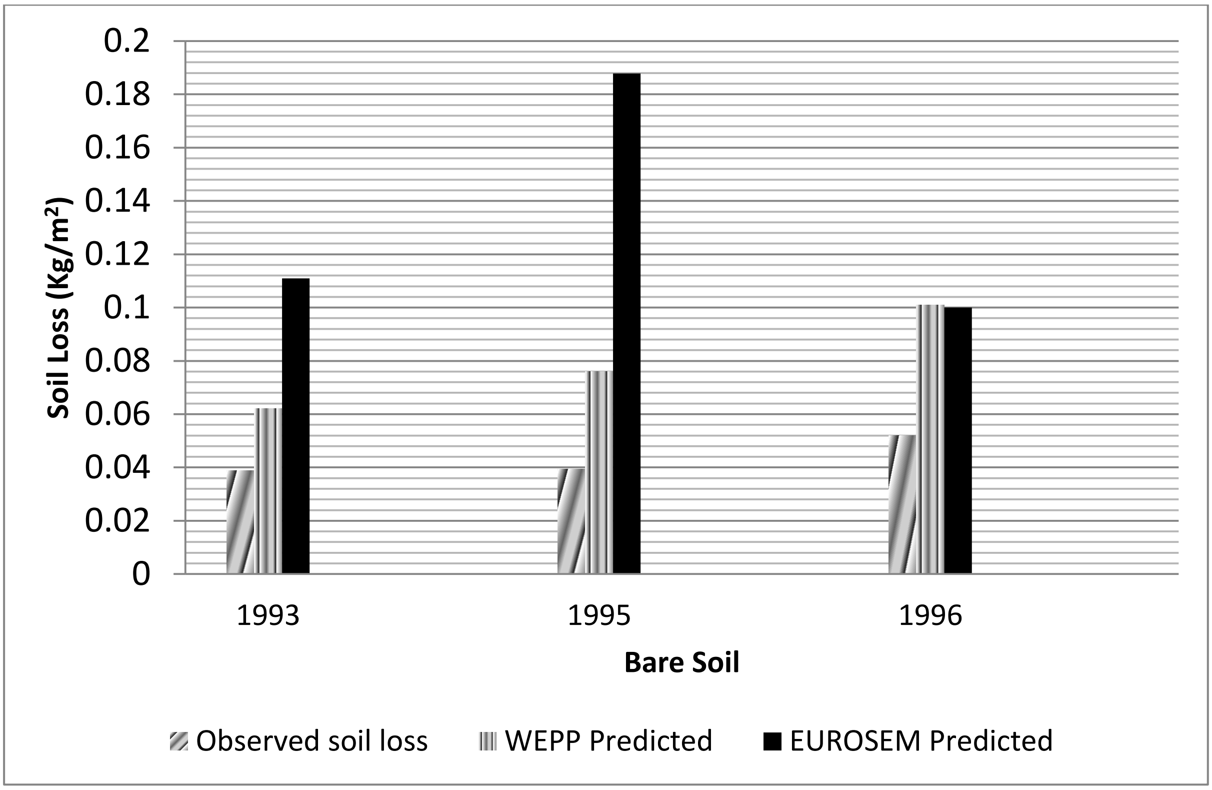

Fig 1: Variation of Observed and Predicted values of soil loss for bare soil

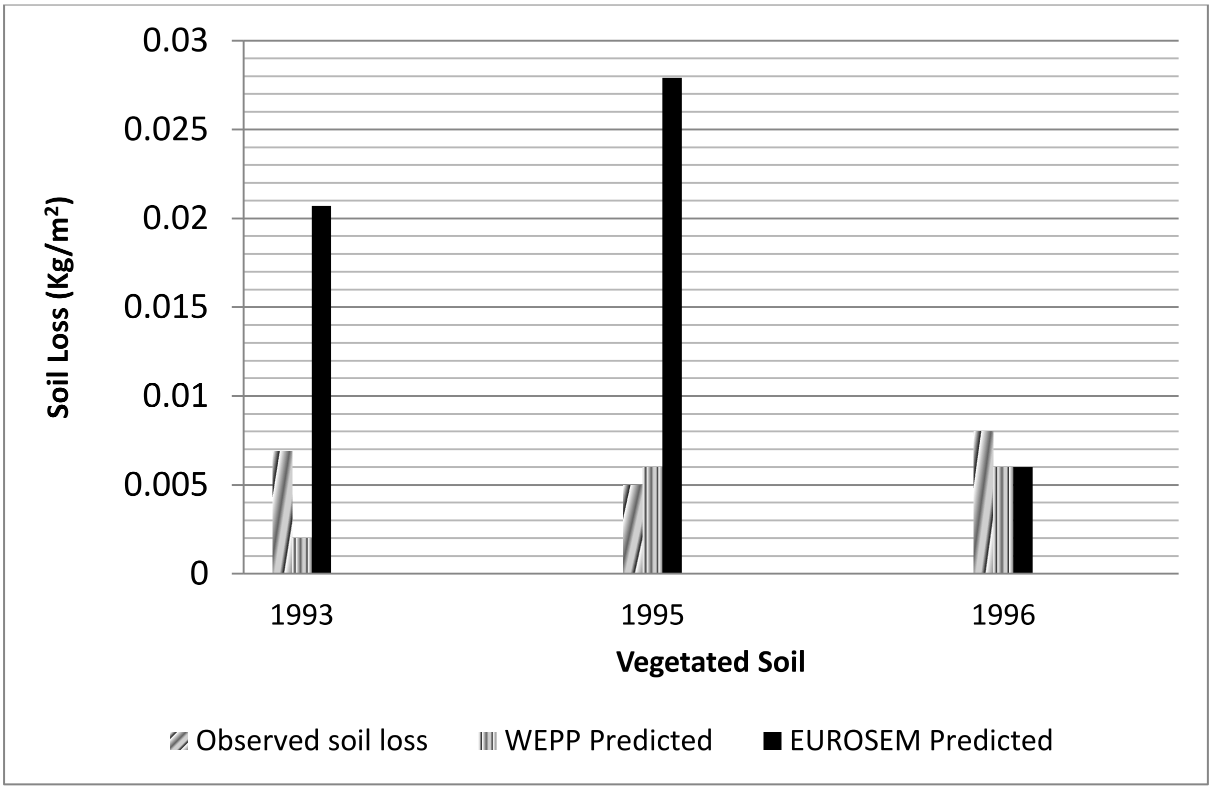

Fig 2: Variation of Observed and Predicted values of soil loss for cultivated soil

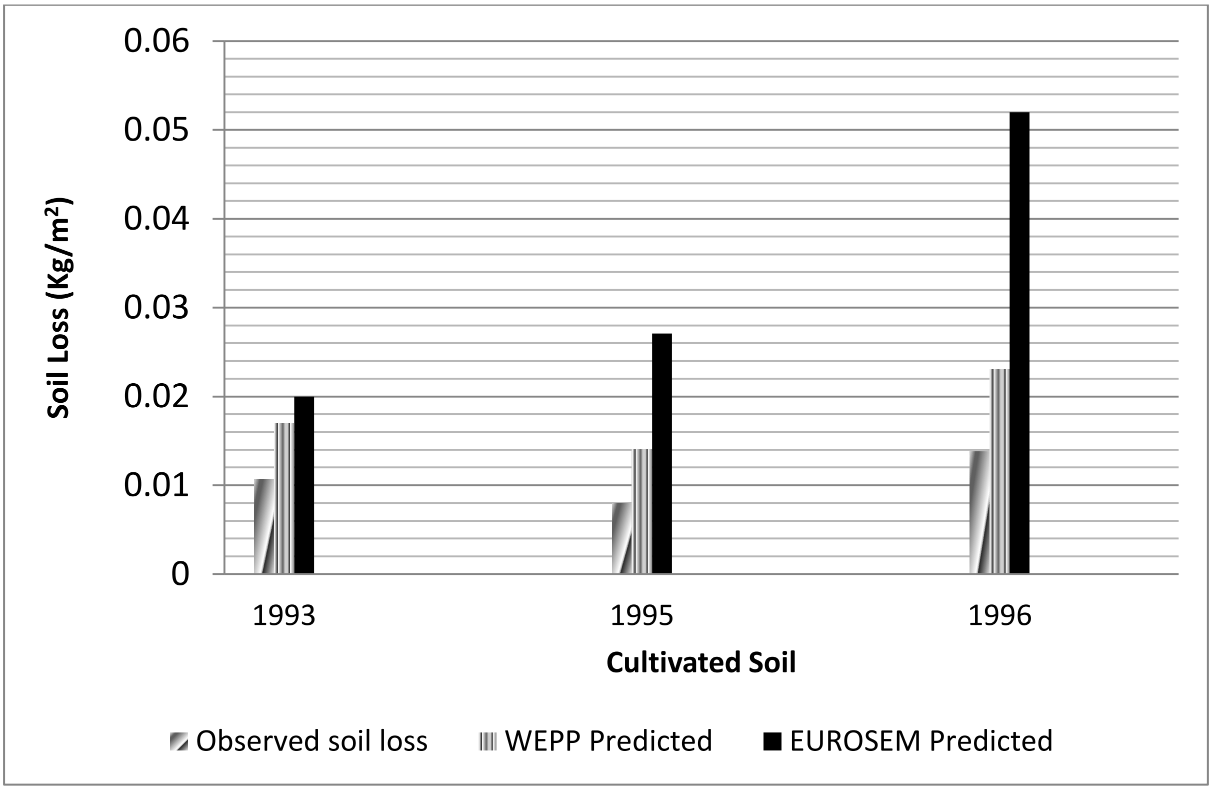

Fig 3: Variation of Observed and Predicted values of soil loss for cultivated soil

4.1 Model limitations

- The WEPP model does not explicitly include hydrodynamic channel network flood flow routing or sediment transport algorithms. The model simulates hydrodynamics and sediment transport by using a simplified hydrologic model and a single sediment transport capacity equation [20].
- To simulate water routing from hillslopes, to and through a channel network, WEPP applies modifications to the Rational [21] and Soil Conservation Service Curve Number [22] methods. These methods are not rigorous, since they are only capable of determining the peak runoff and/or volume [23], and they ignore the physical processes governing open channel flow.
- WEPP-Hillslope model stores only daily summary information, even though it generates sub-daily hillslope runoff and sediment delivery information. This imitation precludes the model from being fully integrated with other watershed models that require sub-daily time series data. [24]
- The WEPP watershed model is not applicable to areas containing classical gullies or stream channels which may have (1) head cut erosion, (2) sloughing of gully sidewalls, (3) seepage effects on erosion in channels, (4) perennial stream channels, or (5) partial area hydrology [25]
- In EUROSEM, the requirements for sub-hourly rainfall data restrict breadth of application due to limited availability. The model is most appro-priate for cultivated land on sloping topography and difficulties may be encountered elsewhere. [26]

5. Conclusion

The following conclusions are therefore drawn:

1. WEPP showed better prediction over EUROSEM for the three consecutive years for bare and cultivated soils.
2. WEPP is therefore recommended for soil loss prediction in bare and cultivated soils in Samaru.
3. Another soil erosion model should be used for soil loss prediction in vegetated soils as the two models under review did not give consistent predictions.

References

1. Adewumi, J.K., Mudiare, O.J., Owonubi, J.J. Soil loss estimation in Samaru, Zaria: Using European Soil Erosion Model In: Agunwamba, J.C., Chukwuma, G.O., Mbajiorgu, C.C. (Eds.). Book on Proceeding of the First regional symposium on Hydrology of Tropical Watersheds. DE- Adroit Innovation 1997 pp. 133-145

2. Nwakwasi, N.L. and Tee, D.P. Statistical prediction of gully erosion development on the coastal plain sands of the South Eastern Nigeria. Nigerian Journal of Technology Vol. 24, No 2, 2005, pp. 59-66

3. Ogbonna, S.U. Understanding the mechanism of soil erosion from outdoor model study. *Nigerian Journal of Technology* Vol. 16, No 1, 1995, pp. 10-18.

4. Erlangung des Grades. Modeling soil erosion and reservoir sedimentation at hill slopes and catchment scales in semi-arid Burkina Faso. Inaugural-Dissertation 2010 http://hss.ulb.uni-bonn.de/2011/2483/2483-1.pdf

5. Beven, K.J. Changing ideas in hydrology - the case of physically-based models. *Journal of Hydrology* Vol. 105, 1989 pp. 157-172

6. Szilassi, P., Jordan, G., Van Rompaey, A., Csillag, G. Impacts of historical land use changes on erosion and agricultural soil properties in the Kali Basin at Lake Balaton, Hungary. *Catena* Vol. 68, 2006 pp. 98–108

7. Kirkby, M. J., McMahon, M. L. MEDRUSH and the Castop Basin – the lessons learned. *Catena* Vol. 37, 1999 pp. 495–506

8. Renard, K., Foster, G., Weesies, G., McDool, D. and Yoder, D. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). *USDA-ARS Agricultural Handbook* No 703, 1997

9. Young, R.A., C.A. Onstad, D.D. Bosch, and W. P. Anderson. AGNPS: A nonpoint-source pollution model for evaluating agricultural watersheds.

Journal of Soil Water Cons. Vol. 3, 1989 pp. 168—173

10. Beasley, D.B., Huggins, L.F., Monke, E.J. Answers: A model for watershed planning. *Transaction of the ASAE* Vol. 23, 1980 pp. 938-944

11. Morgan, R. P. C., Quinton J. N., Smith, R. E., Govers, G., Poesen, J. W. A., Auerswald, K., Cnisci, G., Torri, D. and M. E. Styczen. The European Soil Erosion Model (EUROSEM) – a dynamic approach for predicting sediment transport from fields and small catchments. *Earth Surface Processes & Landforms* Vol. 23(6), 1998 pp. 527-544

12. Rose, C. and Yu, B. Dynamic process modeling of hydrology and soil erosion In: F. P. de Vries, F. Agus, and J. Kerr, (Eds.). Soil Erosion at Multiple Scales: principles and methods for assessing causes and impacts. *CAB International* 1998 pp. 269-268.

13. Tiwari, A. K., Risse, L. M., Nearing, M. A. Evaluation of WEPP and its comparison with USLE and RUSLE. *Trans. ASAE* Vol. 43, 2000 pp. 1129–1135.

14. Morgan, R. P. C., Quinton, J. N., Smith, R. E., Govers, G., Poesen, J. W. A., Auerswald, K., Chisci, G., Torri, D., Styczen, M. E., and Folly, A. J. V. *The European Soil Erosion Model (EUROSEM): Documentation and user guide.* Silsoe College, Cranfield University, UK. Version 3.6, 1998b pp. 89.

15. Morgan RPC, Quinton JN, Rickson RJ. *EUROSEM user guide.* Silsoe College, Cranfield University, Silsoe, UK. version 3.1, 1993

16. U. S. D. A. Soil Taxonomy. *A basic system of soil classification for making and interpreting soil surveys*. Washington D.C 1975 pp. 475

17. FAO/UNESCO Soil map of the world: 1:5,000,000. Vol. 1, *1974 Sheet and Memoir Paris* pp. 59

18. Oikeh, S. O., Chude, V. O., Carsky, R. J., Weber, G. K. and Horst, W. J. Legume rotation in the moist tropical savanna: Managing soil nitrogen dynamics and cereal yields in farmers' fields. *Experimental Agriculture* Vol. 34, 1998 pp. 73-83

19. Nearing, M.A. Why soil erosion models over-predict small soil losses and under-predict large soil losses. *Catena* Vol. 32, 1998 pp. 15–22

20. Ascough, J. C., C. Baffaut, M. A. Nearing, and D. C. Flanagan. Watershed model channel hydrology and erosion processes. In: Flanagan, D. C. and Nearing, M. A. (Eds.). *Technical Documentation: USDA-Water Erosion Prediction Project (WEPP).* USDA-ARS National Soil Erosion Research Laboratory West Lafayette, Ind. 1995, Chapter 13

21. *U.S. Army Corps of Engineers.* Flood-runoff analysis 1994 EM 1110-2-1417

22. USDA-SCS National Engineering Handbook Section 4: Hydrology. *U.S. Government Printing Office* Washington, D.C., 1972

23. McCuen, R. H. *Hydrologic Analysis and Design* 2nd ed. Prentice-Hall, Upper Saddle River, N.J. 1998

24. W. J. Conroy, R. H. Hotchkiss, W. J. Elliot. A coupled upland-erosion and in stream hydrodynamic-sediment transport model for evaluating sediment transport in forested watersheds*. Transactions of the American Society of Agricultural and Biological Engineers* Vol. 49(6), 2006

25. Ascough, J. C., Baffaut, I. C., Nearing, M. A. and Liu, B. Y. The WEPP watershed model: Hydrology and erosion. *Trans. ASAE* Vol. 40(4), 1997 pp. 921-933

26. Sharpley, A.J., Robinson, J.S. and Smith, S.J. Assessing environmental sustainability of agricultural systems by simulation of nitrogen and phosphorus loss in runoff*. European Journal of Agronomy*, Vol. 4, 1995 pp. 453-464.