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Four Decades of Progress in Monitoring and Modeling of Processes in the Soil-Plant-Atmosphere System: Applications and Challenges

Testing different topographic indexes to predict wetlands distribution

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Abstract

Rural landscapes are characterized by great heterogeneity, thus for any policy of landscape protection and management, the delineation of landscape structures is a prerequisite and the demand for such information at the scale of large catchments or basins. Focusing on wetlands, different studies proposed indexes to predict their extension, based on topographic and climatic information, mainly within small order catchments. The topic of this paper is to determine the validity of different indexes for different orders of catchments and to propose an improved index predicting the delineation of wetland for large order catchments.
The work is based on a 830 km² basin where the actual extension of wetlands is partially known on the base of a soil map. We checked the efficiency of different topographic and hydrological indexes as the climato-topographic index and others, by comparing the map of predicted and actual wetlands, for different stream orders. Results have showed that we improved the prediction of wetland delineation for large catchments when we took into account the importance of the flatness of the bottomland. We proposed the ordinated climato-topographic index that reflects this effect in including the local downhill difference in level to the stream, weighted by the drained volume by the stream as an indicator of the stream order. Such index allows environmental stakeholders a better prediction of wetlands at the management scale.

Keywords: wetlands; topographic indexes; stream order.

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Nomenclature

CTI	clima-topographic index
cst	constant
DTM	Digital Terrain Model
$\Delta Z_{downslope}$	downslope difference in elevation
OCTI	ordinated climato-topographic index
Slp_{local}	local slope
$Slp_{downslope}$	downslope slope
STI	soil-topographic index
TI	topographic index
T	transmissivity
Vr	drained volume

1. Introduction

1.1. The importance of wetlands in the aim of reducing non point pollution

Rural landscapes are characterized by great heterogeneity. Land use mosaic usually shows different patches, with variable size, that cover the land. Some of these patches are non agricultural landscape structures such as hedges, ditches, watercourses, roads. Agricultural fields could be sources of diffuse pollutants, such as nitrogen and phosphorous, while the other landscape structure could be sinks, waterways or could act by diluting the pollutant. Experimental studies at the field scale can provide estimates of pollutant emissions by different cropping system; on the other side it is possible to evaluate the pollutant losses at the catchment scale by monitoring. The relationship between input and output is very complex and variable, due to landscape structures, storage in the soil, transfer time, the occurrence of particular climate conditions (intense precipitations, drought periods) and due to the uncertainty that characterizes these variables and natural phenomena. Even if field emissions could be measured experimentally or estimated by using the agricultural mass balance and regional references on the rate of soil transformation, it is almost impossible to control and predict all the process that can take place between the emission point and the outlet [1]. Consequently, it is difficult to assess nutrient retention – when it happens- due to landscape structures simply by comparing field emissions and fluxes at the outlet. A better approach is providing a set of variables to assess the limits and the possibilities for quantifying nutrient retention impacts both at local and at landscape scale, as Viaud et al. studied in 2004 [2]. Different studies have been conducted to define the spatial distribution of those landscape structures that are able to influence the pollutants' load between the source of emission, mainly the field, and the flux at the outlet of the considered catchment. Muscutt et al. (1993) [3] define buffer zone as a landscape structure set between the source of water pollutant and the receiving water body that may provide a physical and/or biogeochemical barrier against pollutions inputs; in extreme situations buffer zone can act as sinks. Considering mainly the phosphorous and the nitrogen as nutrients to take into account in this context, the insoluble phosphorus and organic nitrogen retention capacity of the buffer zone is influenced by the reduction of overland flow (by promoting infiltration) and by the reduction of sediment load in overland flow water (by reducing flow velocity and filtering due to vegetation cover). The sustainability of the buffer zone will depend on other processes that will limit the mobility of the accumulated pollutants, essentially physical adsorption, biogeochemical transformations and maintenance operations such as tillage, re-seeding, mowing [4,5]. In the case of nitrates and soluble P, the major processes involved in the buffering effect are essentially biological or microbiological: plant uptake, microbial assimilation, denitrification. The role of different types of buffer zones can be examined according to this general framework, on one hand, the local factors controlling the retention processes and, on the other hand, the landscape context determining the overall buffering capacity of the catchment.

Wetlands have the main role of buffer zones thanks to their capability of retention of the pollutants by denitrification, uptake by vegetation, by dilution in the absence of significant nitrogen inputs [6]. They appear as important landscape structure from a hydrological point of view because they are at the interface of surface flow, river flow and groundwater exfiltration [7].

Wetlands, especially the valley bottom wetlands, are characterized by superficial shallow groundwater and represent an interaction element of the catchment. They reach the saturation seasonally due to the fluxes, more or less superficial, that come from the hillslope. The gradient is able to influence the water's movements towards the deeper aquifer. It has been studied that the hydrographic network influences the wetlands; in particular it has been estimated that until the second or third Strahler order there is a dominant interaction between the wetlands and the hillslope; whereas beyond the third order the river configuration contributes with the versant to influence directly the wetlands function. The wetlands are areas where transfer of flows could occur; they are able to stock the water that comes from the hillslope (groundwater, runoff) as well as the river water after inundation phenomena.

Wetland management for diffuse pollution control could be an interesting support to good agricultural practices. In this aim it is fundamental to define the usable area and the methods to maintain them. The delineation of wetlands is a prerequisite for any policy of wetland protection and management, and there is an increasing demand for such information at the scale of large catchments or basins that is the management scale. The development of GIS and DTM allowed scientists to propose methods aimed to predict in an easy way the delineation of wetlands, when ground-based information is not available. To identify wetlands, Merot et al. [8] dealt with the distinction between potential, existing and efficient wetlands by using different criteria.

1.2. Indexes to define wetlands' spatial distribution

In this context it is necessary to have a realistic knowledge of the spatial distribution of wetlands within the landscape, first of all for their non-point pollution control and their influence on the ecosystem. One of the first methods to predict their spatial distribution was to consider the geomorphology of catchments, because topography is the driving force of water movements. The wetlands location depends mainly on flowpath convergence, slope and the hydraulic conductivity of the soil. Different indexes have been developed to estimate the location of wetlands. Beven and Kirkby [9] and Beven [10] defined a topographic index (TI) that considers the local slope and the upslope drainage area. It is based on the hypothesis that the hydraulic gradient of the shallow water table is equal to the local topographic slope angle. In this hypothesis and for a given rainfall depth, the larger is the drainage area and the smaller the slope, the higher is the topographic index. Its equation is:

$$TI = \ln\left(\frac{a}{\tan\beta}\right) \qquad (1)$$

where a is the drainage area and β is the local slope. Considering also the transmissivity T, that usually can be neglected compared to the variations of slope and drainage area, the index becomes a soil-topographic index (STI) with the equation:

$$STI = \ln(\frac{a}{T \tan \beta}) \tag{2}$$

This kind of indexes required homogeneous rainfall depth to let a comparison between different areas. To obtain a more robust index, it is necessary to introduce the effective rainfall depth, namely the net rainfall that is no evaporated or transpirated. Hence the index becomes a clima-topographic index (CTI) whose equation is:

$$CTI = \ln(\frac{V_r}{\tan \beta}) \tag{3}$$

where Vr is the volume of annual effective rainfall, obtained by multiplying the drainage area with the effective rainfall. In this index the downhill slope (the slope between the point of interest and the river course) is used instead of the local slope [11]. In the previous approaches we considered, there are only upslope or local variables that control the wetland indexes and, consequently, the location of the wetlands within the catchment is not taken into account. Some field observations and conceptual approaches conduct us to analyze the influence of the catchment order on the wetland prediction. It is necessary to test the relevance of the influence of the conditions downstream with the river and catchment order [12].

The *TI*, first proposed by Beven and Kirkby [9], in the framework of hydrological modelling, was applied to predict the delineation of wetlands in headwater catchments [13,14]. Some improvements were proposed to this *TI*, for instance including the effect on the wetland prediction of the gradient of the mean annual precipitation over the catchment, as it was done in the *CTI* [12]. But some questions arose when people considered large catchments. It is recognised that the assumption on the hydraulic gradient is not always valid close to the stream network, where inverse gradients, from the stream to the bottomland may occur, depending on the water conditions [15,16]. Moreover, one of the conditions for applying the Darcy law is the downslope free water movement in the groundwater. Results at the local scale [17,18] showed the ability of water exchanges from the watercourse to the groundwater of the riparian wetland.

The aim of the present study is to check the validity of topographic indexes when the connectivity and the interaction between the stream course and the riparian wetland are relevant, as it is recognised when the Strahler order [19] of the catchment increases [20,21].

A comparison between the maps of predicted and actual wetlands was made for different stream orders, to test the efficiency of the different topographic and hydrological indexes. It has been showed that the prediction of wetlands for large catchment is more reliable taking into account the flatness of the bottomland.

We considered necessary also to propose an improved index for the delineation of riparian wetlands in large order catchments considering the local downhill difference in level to the stream, weighted by the drained volume by the stream, as an indicator of the stream order. The efficiency of this new index, called ordinated-climato-topographic, was first tested by Montreuil et al. in the Scorff River Basin (480 km^2), in the Britanny region of France. In this framework the study area is the Seiche River Catchment (830 km^2), that belongs to Ille-e-Vilaine department, east Brittany (Fig.1 (a) and (b)).

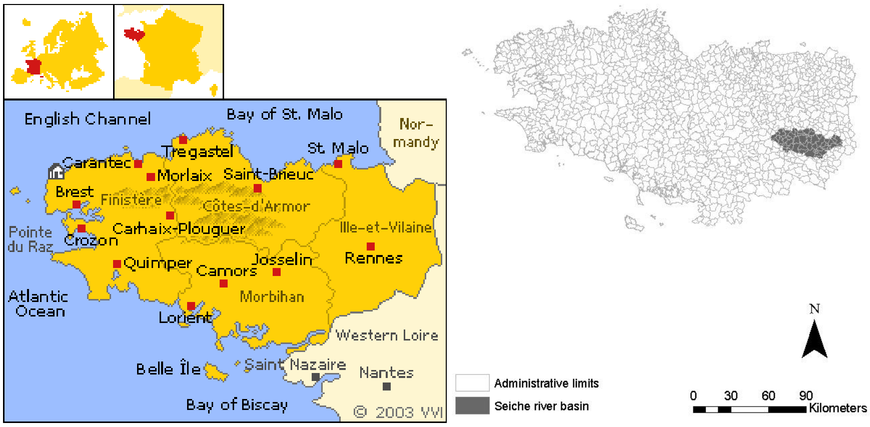

Fig. 1. (a) Brittany region; (b) Seiche river basin

2. Material and methods

2.1. Site description

The region has an oceanic climate with effective rainfall roughly estimated as 165 mm per year. The Seiche River Basin has a surface of 830 km^2, the river's length is 95 km. The Seiche's source has an altitude of 160 m while the outlet 15 m.

The catchment mainly is schist, so the soil is not permeable. The river flow is not regulated by the groundwater and mainly depends on the rainfall. The average annual flow is 4.60 m^3/s but the catchment is characterized by severe drought and floods quite strong depending on the season. The Seiche presents in fact seasonal flows very marked, as so often in the east of Brittany: high waters in winter (December to March) with the average monthly flow between 7.3 and 12.1 m^3/s, and very low water in summer (early June to October) with a decline in the average monthly flow to 0.286 m^3 in August. There are some areas of expansion of floods upstream and in the middle of the Seiche basin. They can reduce the risk of flooding downstream. Land use is characterized by a very open landscape with few hedgerows and embankments. The corresponding SAU (Used Agricultural Surface) is 57 800 ha mainly occupied by traditional agriculture and dairy cow and pig livestock. In 2001, pasture covered about 65% of the SAU, followed by cereal and maize crops (respectively 25% and 10%) [22]. The remaining areas (about 250 km^2) was characterized mainly by non cultivated soils (25%), woods (20%) and urban areas (15%).

2.2. Material

In the aim of this study it was necessary to analyze data layers required to define the different topographic and hydrographic indexes and to test their efficiency and their relation with the catchment features.

A partial 1: 25 000 soil map that covers about 140 km^2 of the Seiche catchment is available. Soils are classified according to four criteria: geologic material, intensity of hydromorphy, soil profile and soil depth. This map identifies an area of about 33km^2 characterized by hydric soil (Fig.2).

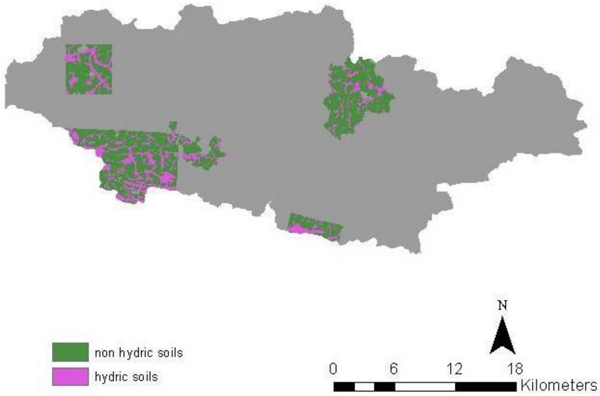

Fig. 2. Partial soil map of the Seiche river basin

The different index calculations were based on the Digital Terrain Model (DTM) of the Seiche catchment characterized by a 50m pixel size. The drainage network was considered as the total set of surface flow pathways in the catchment. In a DTM, the surface flow direction of each pixel was drawn according to the difference of elevation of the contiguous pixels [23]. Two kinds of models may be used: the multi-directional model and the eight flow direction model (D8) also called mono-directional model. The former assumes that runoff flows from a processing pixel in all downslope directions following a weighting algorithm [24,25,26]; the latter assumes that runoff flows only in the steepest downslope direction. It has been demonstrated [27,28] that the use of a multi-directional model is strongly convenient for topographic wetland prediction. On the other side, the mono-directional model is more suitable for modeling the hydrographic network. The hydrologic elaborations based on DTM were developed by the software MNTSurf [29].

Discontinuities in the drainage network linked to the generation of DTM create drainage anomalies, i.e. points without outlets. These anomalies are corrected iteratively by virtually filling the points until the connection with a mesh of lower altitude.

The drainage network is, so, divided in 2 parts: the hillslopes with a multidirectional model and the hydrographic network with a monodirectionnal model. Extracting the hydrographic network from the modelled drainage network shows limitation due to the misfit in the location between the modelled and the observed stream network [30], specifically on the flat areas. We chose to impose the hydrographic network given by the National Geographic Agency (BD Hydro, from IGN) as a constraint for the DTM. Nevertheless the choice of this network leads to underestimate the length of the headwater functional stream network in this region, where the stream course expands in winter. This underestimation may concern up to 20% of the total length of the stream network. To complete this hydrographic network we adopted the method proposed by Aurousseau and Squividant in 1996 [31] and by Merot in 2003 [12], that defined the hydrographic network as the part of the drainage network that drains the volume of effective rainfall exceeding a threshold volume. This threshold was empirical, defined as the mean value of drained volume observed at the sources of the vectorised network, it was fixed equal to $65 \cdot 10^3$ m^3 for all the Brittany region.

The 1: 25 000 vectorial soil map was rasterized considering a cell size of 50 m. A raster map, with a 50 m pixel size, of the Seiche basin was characterized considering the Strahler order for each sub-catchment; the higher Stralher order recorded is five for this basin.

In summary for this study we have three main maps:

- a soil map that covers 140 km^2
- a topographic map
- a stream network with the Stralher classification

2.3. Definition of variables and indexes

The topographic variables are showed in figure 3.

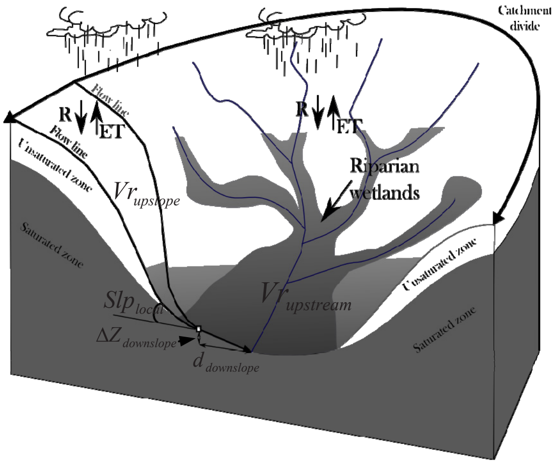

Fig. 3 Topographic and hydrological variables and indexes. R: rainfall depth, ET: evapotranspiration depth, $Vr_{upslope}$: upslope drainage volume, Slp_{local}: local slope, $\Delta Z_{downslope}$: downhill difference in elevation, d*downslope*: drainage length to stream, $Vr_{upstream}$: upstream drainage volume.

The *downslope difference in elevation* ($\Delta Z_{downslope}$) was defined as the difference in elevation between the point of interest and the stream network, measured along the hydraulic path (Gascuel-Odoux et al., 1998).

The *local slope* (Slp_{local}) is used to calculate the ordinated climato-topographic index.

The *downslope slope* ($Slp_{downslope}$) is the topographic gradient between the point of interest and the stream course, measured along the hydraulic path. It was calculated taking into account the downslope difference in elevation and the downslope drainage distance between the point of interest on the hillslope and the stream network.

The *drained volume* (*Vr*) corresponds to the drained area at the point of interest, multiplied by the mean annual affective rainfall. This variable is an indicator of the upslope climatic and topographic condition that could control the wetness of soil.

The *topograpchic index* (TI) as defined above. A TI map of Brittany is available on Agro-Transfert Bretagne website to identify the potential wetlands.

The *climato-topographic-index* (CTI), as defined above, that corresponds to the previous TI modified by considering the effective drained volume (*Vr*) and the local slope (Slp_{local}). It had been validated in studies conducted by Merot et al. (2003), it mainly assumes that saturation is controlled by upslope conditions.

$$CTI = \ln\left(\frac{V_r}{\tan Slp_{local}}\right) \tag{4}$$

In order to test the increasing influence of stream order in the control of the wetland extension from upstream to downstream, the climato-topographic index was modified. The flatness of the bottomland characterised by the downslope difference in elevation ($\Delta Z_{downslope}$) and weighted by the volume drained by the stream (that is an indicator of the upstream-downstream location, $Vr_{upstream}$, and was calculated following the mono-directional modelling criteria) was included in a new index, called the *ordinated climato-topographic index*, OCTI, in the following way:

$$OCTI = \ln\left(\frac{Vr}{\tan Slp_{local}}\right) + cst \cdot \frac{\ln Vr_{upstream}}{\left(\Delta Z_{downslope} + 0.1\right)} \tag{5}$$

The value 0.1 was added to $\Delta Z_{downslope}$ to avoid a division by zero for sites without sufficient elevation resolution to distinguish riparian wetland elevation and stream elevation. A constant (*cst*), expressed in the opportune measure unit, was added to weight the mean influence of upslope and downslope variables.

Among this variables and indexes we need to define which of them will be considered indexes able to predict wetlands.

Three elementary variable will be considered as possible predicting indexes:

- $\Delta Z_{downslope}$
- $Slp_{downslope}$
- Vr

The local slope Slp_{local} , used in the OCTI, can not be considered an efficient indicator to identify hydric soils, because it is possible to find flat areas or areas with a low gradient at the top of the hillslope, where there is no shallow groundwater.

Three combined indexes are considered able to predict wetlands:

- *TI*
- *CTI*
- *OCTI*

2.4. Definition of hydric soils

Hydric zones are generally defined as the areas where soils are affected by redoximorphic features in the topsoil horizon (<20 cm depth). The index‘s values (and *cst* for OCTI) were calibrate by giving the optimal delineation of the hydric soils, for the different indexes. For this aim it was hypothesized that soils with hydric class between six and nine are hydric soils. This choice was done by comparing the soil map 1: 25 000 with the TI map. Considering the classes six to nine let a more precise estimation of the hydric solis.

2.5. Calibration of the indexes

The calibration was based on the percentage of hydric soils that was forced to be the same for the predicted than the observed rasterized soil map. The quality of the prediction was assessed by the percentage of pixels that were well predicted compared to the total of the observed hydric soils. In this way it was possible to define the threshold of identification of hydric soils for each index. The second step was to estimate the Strahler order influence on the quality of the indexes' prediction.

3. Results

Results are first presented considering the distribution of the index for the actual hydric and non hydric soil. Then we define the best threshold of each index that allow to predict the hydric soil with the best ratio between over and under estimation. Figure 4 shows the percentage of hydric soils predicted by each index.

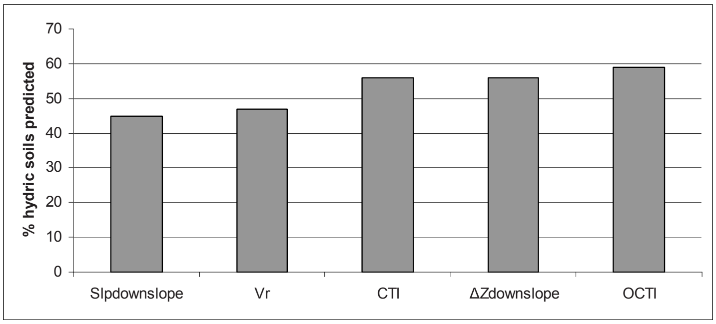

Fig. 4. Percentage of predicted hydric soils by topographical and hydrological indexes

In the Seiche basin, the *downslope slope* ($Slp_{downslope}$) ranges from 0% to 42%. For hydric soils it varies between 0% and 16% while for no-hydric soils it varies from 0% to 28%. The best $Slp_{downslope}$ threshold defined that allow us to identify the 46% of the hydric soils is 1.5%. Nevertheless the ratio between overestimation and underestimation is 63%, that shows an underestimation.

The *downslope difference in elevation* ($\Delta Z_{downslope}$) between the point of interest and the stream network, considering the whole catchment, reaches 88m with a mean value of 10m. For the non-hydric soils the $\Delta Z_{downslope}$ value ranges between 0 and 50m, while for hydric soils it ranges between 0 and 45m. The average values are respectively 11m for non-hydric soils and 6m for hydric soils. Fixing a threshold of 3.75 m allowed us to identified the 56% of the hydric soil.

The annual volume of effective rainfall drained by soils, $Vr_{upstream}$, reaches $140 \cdot 10^6$ m^3 considering the whole catchment, with a mean value equal to $360 \cdot 10^3$ m^3. Both for the hydric and the non-hydric soils the ranges between 0,25 and $135 \cdot 10^6$ m^3. The average value are $1117 \cdot 10^3$ m^3 for hydric soils and $55 \cdot 10^3$ m^3 for the non-hydric. The threshold that gives the best delineation of hydric soils is $2.8 \cdot 10^3$ m^3 with 47% predicted.

The *climato-topographic-index* (CTI) lets a prediction of the 56% of the hydric soils if the threshold is fixed at 5.29. The hydric soils have an average CTI equal to 7.5 while for the no-hydric soils it is 4. The respective ranges are 1,25 to 24 and 0,24 to 24. Considering the whole catchment CTI ranges between 0 and 24 with a mean value equal to 5.

For the *ordinated-climato-topographic* (OCTI) the constant value was chosen by iterative calculation that conducted to a constant (*cst*) equal to 1.7 m. The OCTI values are between 0,88 and 336 in the whole catchment and the mean is 18.5. The hydric soils are characterized by an OCTI that ranges between 2.41 and 336 with a mean of 44, whereas for the other soils the range is 1,27 to 336 and the mean is 9. The threshold fixed to predict the 59% of the hydric soil is 8.28.

3.1. The influence of the Strahler order

The Seiche basin is a fifth order catchment. Considering the partial soil map, the 65% of the areas belong to the first-order subcatchments. When the order increases, the corresponding soil map areas decrease, for example only the 4% of the soil map areas are of the fifth order (Fig. 5 (a)). Figure 5 (b) shows that considering the whole catchment most of the areas belong to the second Strahler order.

The low contribution of the high order stretches of catchment, if we consider the areas covered by the partial soil map, determines that the calibration of the different indexes is mainly determined by the characteristics of the first-order catchments, when the Strahler order is not taken into account. The percentage of hydric soils is quite stable in relation to the change of stream order: for the order 1,2,3,4 the average percentage of hydric soils is 25%, while for the fifth order this percentage increases and reaches 38% (Fig. 6).

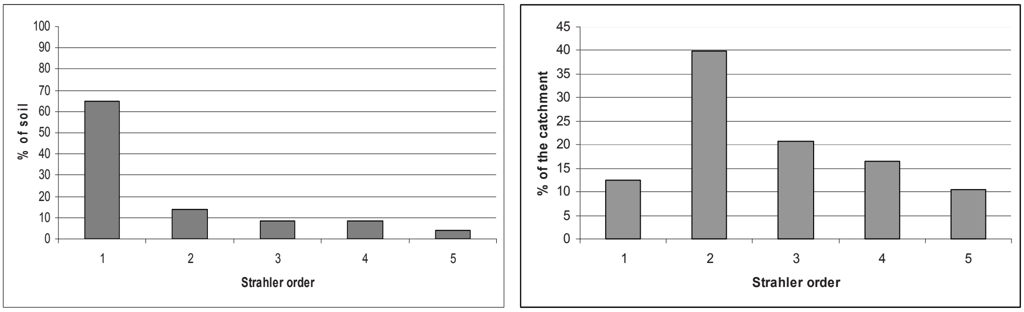

Fig.5. (a) Availability of soil data according to the Strahler order; (b) Percentage of subcatchment areas according to the Strahler order.

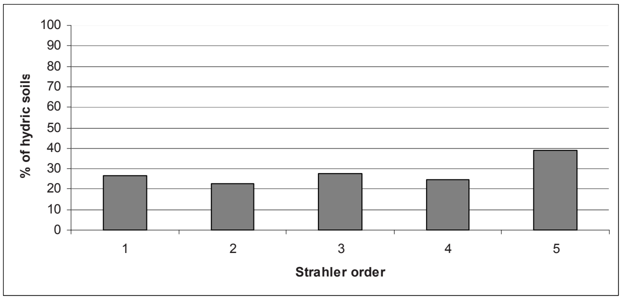

Fig. 6. Percentage of hydric soils in relation to the Strahler order

The prediction quality for the hydric soils varies with Strahler order of the catchment stretches. Figure 6 represents the value of the prediction according to the order and figure 8 the quality and the stability of this prediction.

- For the *drained volume* $Vr_{upstream}$ the prediction quality decreases with the increase of the order.
- The *downslope slope* $Slp_{downslope}$ seems to be a good index to predict hydric soils but it is quite unstable if the catchment order changes.
- The *climato-topographic* (CTI) and the *ordinated climato-topographic* (OCTI) indexes have the more stable behaviours through the five order.

- The *difference in elevation* $\Delta Z_{downslope}$ could not be considered as an reliable index because it overestimates too much.

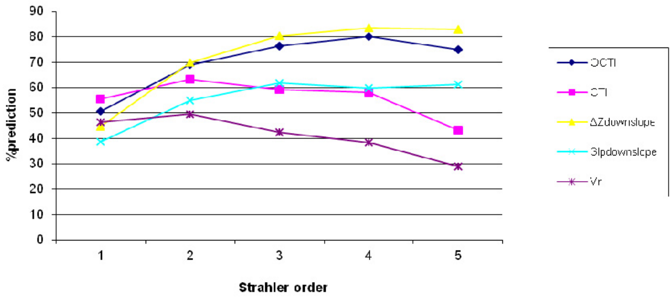

Fig. 7. Prediction percentage of hydric soils for the different indexes in relation to the Strahler order

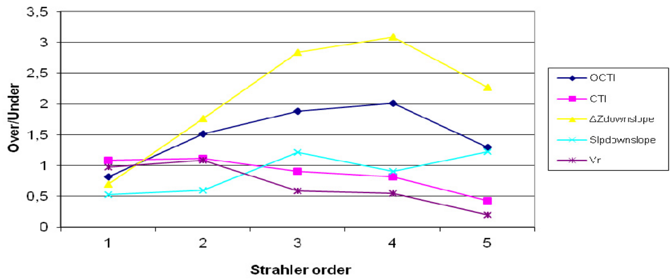

Fig.8. Ratio between percentage of the over and the under estimated hydric soils for each index

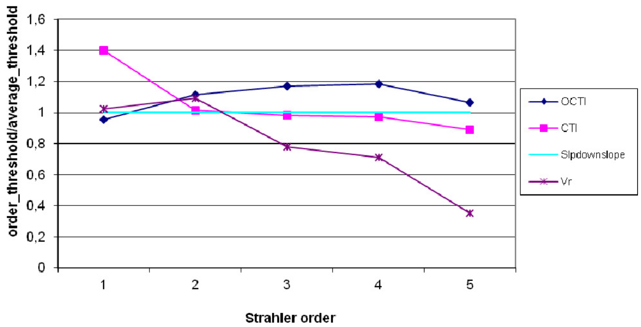

Fig.9. Ratio between the threshold calibrated considering the Strahler order and the mean threshold defined without the Strahler order.

A further consideration should be done analyzing the behaviour of the ratio between the thresholds fixed considering each order and the thresholds corresponding to the global catchment (fig. 9). This ratio allows us to verify if the degradation of the hydric soils prediction is due to an underestimation of the soil saturation, which is proportional to the threshold. For each order, a threshold value less than the threshold chosen for the all catchment shows an underestimation of the saturation area.

Figure 9 shows that the CTI and the OCTI present a stable ratio and it means that their prediction is reliable and stable in changing the Strahler order. Nevertheless the CTI seems to overestimate hydric soils for lower order.

The downslope slope presents a stable behaviour mainly for physical reasons: the lower the downslope is the more saturated the corresponding area usually is [32].

4. Discussion

This study attempted to quantify the effect of the changes observed in the organisation and the functioning of the wetlands when the stream order increases. These changes gave a hierarchy for the topographic and hydrologic factors controlling the extension of the wetlands depending on the stream order.

The degradation of the wetland prediction with the climato-topographic index when the stream order increases, corresponds to an under-estimation of the wetlands area. This demonstrates that the convergence of fluxes, estimated by the climato-topographic index is insufficient to explain the extension of the riparian wetlands in high order streams. Two processes, not taken into account in the climato-topographic index, can contribute to the extension of the riparian wetland when the stream order increases:

- a contribution from the stream to the local saturation of the riparian wetlands
- or a more important retention of the water fluxes from the local hillslope.

The improvement of the delineation of the riparian wetlands in increasing the saturation probability in a way proportional to the water volume drained by the stream and by the inverse of the downhill difference in level represents these processes weighted by the water volume drained by the stream as an indicator of the stream order. The OCTI seems to be the most precise and reliable index to identify wetlands (Fig. 10).

This is consistent with different studies. At a local scale, Burt et al., [15] and Vidon and Hill, [16] showed a more frequent occurrence of an inversion of the hydraulic gradient between the stream and the riparian wetland when the topographic downhill gradient is weak. Even without the inversion of hydraulic gradients, the decrease of topographic downhill gradient corresponds to a decrease of the hydraulic gradients and a slower drainage of the riparian wetland, fostering an increase of the wetland area. These studies show the consistency of the downhill difference of elevation as an indicator of interactions between riparian wetlands and the stream.

On another side, the increase of the volume of alluvium and of associated wetlands referred to the width of the hillslope with the order [33] demonstrates the increasing influence of the stream on the wetland functioning, and the contribution of the stream water to the wetlands during floods. This scheme representing the respective influence of the stream and the hillslope groundwater is consistent with the theoretical framework proposed by Brinson [20], White [34] and Tabacchi et al. [21] and confirms the need to take into account the interactions between the wetlands and the stream to understand their functioning and to model their extension in a large catchment.

The need to identify variables and indexes that allow us to estimate hydric soils in different landscapes is confirmed also by the results obtained by Mourier et al in 2008 [32]. They show that linear correlations between topographic index and hydric soils extent are only significant for low Strahler orders (2 or 3). Although in upper catchment settings the extension of wetlands appears linked to variation of the topographic index, downstream topographic modelling that use simple index appears unable to explain hydric soils extent. These studies also show that the correlation between hydric soils width and the hillslope gradient for orders 2 and 3 is R^2= 0.30 and R^2= 0.58 respectively. For higher orders, the morphological variability is too large and no significant correlation can be estimated (R^2 between 0.01 and 0.02). The conclusions obtained by Mourier et al [32] allowed us to suggest the use of downslope gradient in the topographic indexes to better predict hydric soils.

Although the present study shows that OCTI index better estimates hydric soils and it is the most stable index among those presented in this paper according to the change of order, we still are in an initial phase. The calibration of the OCTI parameters is still empirical and based on the particular catchment considered. Studies conducted by Montreuil [6] on the Scorff river basin (Brittany, France) confirm this lack of reliance in this new index, suggesting us that, probably, new parameters have to be considered.

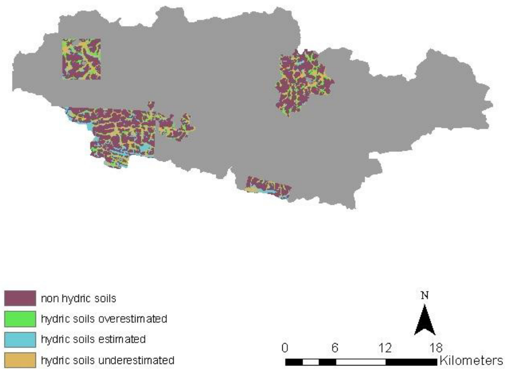

Fig.10 Hydric soils predicted by OCTI

5. Conclusion

The objective of this paper was to improve the prediction of wetland spatial distribution by using different topographic variables and indexes. Firstly the prediction ability of each index was compared with the actual hydric soils distribution. Secondly, it has been showed that the Strahelr order influences wetlands spatial distribution and the prediction of wetland spatial distribution. Figures 7, 8 and 9 show how the different indexes are influenced by the catchment order. Thus it has been studied and developed the OCTI index that allows us to delineate wetland distribution in relation to the catchment's morphology with more reliability. The OCTI index considers the catchment order by using the water volume drained by the stream as a weighting factor. As showed also through the studies conducted by Montreuil (2008) on the Scorff basin, the OCTI has a better prediction quality than the other topographic indexes and variables have. Nevertheless the need of calibrating the constant value *cst* and the threshold proves that the OCTI index is still linked to local scale. Further studies have to be conducted to improve the OCTI efficiency and the possibility to use it in larger scale.

6. References

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