A case study in South-east China of operational pedology as a contribution to a project linking research and training

Laurent Bock, **Gilles Colinet** and Daniel Lacroix

Laboratory of Geopedology, Gembloux Agro-Bio Tech, University of Liege, Belgium, Email geopedologie@ulg.ac.be

Abstract
As a contribution to a European Union project aiming to reduce soil loss in the Upper Yangtze catchment, a full geological, geomorphological and eco/agropedological detailed survey has been carried out in order to appraise firstly the biophysical characteristics of a catchment selected to test modified or novel agricultural techniques and secondly its representativeness of the general mountainous context. Soil samples and topsoil composite samples have been selected from augerings, pits or plots for different analytical menus including mineralogical, physical and chemical characteristics. It was noted that if soil erosion is high and soils are mainly colluvial in nature, some red soils trapped in paleokarstic context are the result of previous weathering periods, thereby limiting the possibility of extrapolating field experiments to other parts of the catchment but also to other red soil areas of Southern China. The basis of a soil information system was launched through a map and its table-legend displaying the characteristics or values of the main unit discriminating criteria. This contribution also offers an opportunity to make Chinese colleagues and practitioners aware of an operational methodology and its associated technologies (field techniques, DGPS, remote sensing, soil laboratory analysis, GIS).

Key words
Soil fertility assessment, local soil database, soil erosion, paleo-features, WRB qualification,

Introduction
This presentation summarizes our contribution to a European Union funded project (1998-2002) entitled: “Improving the productivity and sustainability of crop systems on fragile slopes in the highlands of South China and Thailand”. Our specific objective was to conduct a full survey of the biophysical context to appraise its internal diversity/variability and its external representativeness and to provide the database against which to assess internal change and to ensure the limits of extrapolation. Belgian and Chinese students have been involved and contributed with five Master theses (Vinck 1999; Baudoin 2000; Van Caillie 2000; Baire and Ghuisoland 2001) and one co-supervised PhD (Li 2004).

Material and methods
This study was conducted within the 50 ha Wang Jia Catchment (25°28’32” north, 102°52’50” east), which is located near Kelang village (Kedu Township, Xundian County), 60 km North-north-east of Kunming in Yunnan Province (Southwest China). Altitude ranging between 1,860 and 2,380 m asl, the total elevation difference is 520 m and the mean general slope is 15°. In this region of “Eternal spring”, the mean monthly temperature between 8°C (in January) and 22°C (in June, July and August) and the 1,000 mm rain annual average rainfall characterize a subtropical climate at altitude with the effect of an attenuated monsoon regime (77 % of rains fall between May and September).

According to Jenny’s formulation and facing a lack of information at a relevant scale, the principles of an integrated geomorphopedological and agropedological approach (Bock 1994) have been applied to discern the rock – relief – soil – land cover / land use explanatory relations, soil potentialities and constraints and to assess topsoil fertility versus yields.

In addition to some preliminary work on documents, lithological, geomorphological and land cover/use surveys were carried out by outcrop and landform identification, dip and slope measurements, vegetation / crop observation, (3D) aerial photointerpretation. This work included an assessment of erosion and of soil physical properties, especially water availability for plants. Soils were identified by description of hand augerings down to 120 cm when possible along toposequences and observation of soil pits. Topsoil fertility was assessed in different groups of plots well distributed within the catchment (concept of reference plots or “windows”). Therefore, three sets of samples were collected for different menus of mineralogical, and physico-chemical laboratory analyses.

Results

Main geopedological deductions

With shale, sandstone and dolomitic limestone / dolomite (dolostone), three main lithologies have been identified. A clear influence of lithology and bed strikes on catchment main conformation justifies a subdivision in four main physiographic units i.e. in summit, upper, middle and lower sectors.

Soil stoniness varies from stony on steep slopes and/or positions including sandstone to slightly stony on the catchment floor, soil thickness from 40->120 cm and soil texture from silt loam in shale/sandstone areas to silty clay in some dolomite areas. Moreover the soil colour palette expresses (i) the lithochromic influence of sandstone and shale on the soil colour (yellowish brown), (ii) a reddish shade (2.5YR) in the dolomite environment or, more precisely, in relation to a decarbonated residual product and, (iii) some features of mottling in lower positions.

Therefore, these field observations and the particle size distribution (laser measurement) reveal that soil parent materials could be relatively autochthonous, but are more frequently allogenic and that, from up-stream to down-stream and from subsoil to topsoil, they correspond to an increased mixing of products showing evidence of different deposits.

Main mineralogical deductions

The contribution of the parent rock is clearly shown when the clay mineralogy of a sample of shale or sandstone is considered. The shale is highly micaceous, with subsidiary chlorite, whilst sandstone is more chloritic with subsidiary mica. No kaolinite was detected in this lithological context. It is concluded therefore, that the dominant illite/chlorite assemblage found in the soils is a direct reflection of the influence of the parent material. The illite mineral is likely to be mainly of a muscovitic type and chlorite presents vermiculitic layers even before the onset of weathering. But if the illite content is generally higher than that of chlorite, in certain cases and principally in top horizons, this relation is reversed.

However in dolomitic soils, small amounts of kaolinite and gibbsite occur and are undoubtedly related to pedogenic weathering. Both these minerals require somewhat acid conditions, with depletion of basic cations and, in the case of gibbsite, strong desilication of the system. Therefore, the implication is that the soils are intensively lixiviated and this process would cause the vermiculitisation of chlorite and of mica. The red colour of these soils and the identification of hematite in the bulk samples are consistent with this conclusion and further suggest that this occurs in a warm climate.
Consequently, the dominating presence of chlorite in topsoils suggests a more direct influence of sandstone in the more recent deposits. Therefore, these deposits can cover the reddish material which, trapped in a karstic relief, is probably partly a residual product of dolomite decarbonatation.

Main eco/agropedological deductions

On the most sensitive convex positions, topsoil is acidic (pH H_2O <5.6), low in total organic carbon (TOC <0.6%) and relatively base unsaturated (40-60%). In the most favourable concave positions, topsoil is calcic/carbonated (pH H_2O reaching 8.0), higher in TOC (1.6-2.3%) and base saturated (80-100%); the organic profile is also thicker (1.2-1.5% TOC in subsoil). However, the topsoil C/N ratios with values ranging from 9.0-15.0 suggest that mineralization is optimal or just below optimal on some divide or side positions.

Main physico-chemical and chemical deductions

The CEC results, ranging from 5.3-27.2 $cmol_c$/kg of soil, reflect the main components of the sorption complex, giving an indication of the quality and nature of clay minerals and SOM. Therefore, the best potentialities in terms of the best balance between mineral and organic contents and of the resultant CEC concern the lowest catchment parts (floor and outlet). Upper catchment concave positions on shale and middle catchment sides on dolomite lead to an intermediate diagnosis; the lowest one being for soils on eroded interfluves.

Exchangeable calcium (and magnesium) relates closely to pH results; values > 10 $cmol_c$/kg of soil (and >~3) resulting from carbonate dissolution. Exchangeable potassium content is mainly <0.3 $cmol_c$/kg of soil and compared to the optimum cation balance, exchangeable magnesium ratios are high. Exchangeable acidity being mainly <30% of the CEC, there is no risk of Al toxicity.

Main nutrient availability deductions
From plot fertility assessment (composite samples), if total nitrogen content is greater in concave positions than in other positions and potassium availability is only sufficient in some positions on shale, it appears also that total nitrogen, exchangeable potassium and phosphorus contents are far greater near the village showing the clear impact of fertilization. A plan of pH values confirms perfectly a fertility gradient with low values in upper shale and sandstone soils far from the village and higher values in some dolomitic soils or near the village.

Main typological deductions
According to the World Reference Base for Soil Resources (FAO 2006), soils developed:

(i) on shale and sandstone parent material are Colluvic Regosols (Epi to Endoskeletic, Siltic, Hyper to Orthidystric), also locally Magnesic and Anthric,

(ii) in the vicinity of dolomite outcrops are Luvisols (Siltic, Rhodic) or Thaptoluvic Regosols (Siltic) also locally Skeletic and/or Anthric, Orthieutric to Orthidystric,

(iii) at the catchment outlet near village are namely Gleyic Regosols (Calcaric, Siltic, Anthric).

According to Soil Taxonomy and suggestions made by H. Eswaran, J. Sandor and R. Napoli during the Red Cloud Tour as post-Congress excursion of the 17th International Congress of Soil Science in Bangkok 2002, soils of the second group are Fine-loamy, mixed, hyperthermic Typic Haplustalfs or Rhodustalfs.

Main practical deductions
"Natural" vegetation, as mixed forest, pine trees and bush, is limited to steep slopes with outcrops, stony and/or thin soils. Cultivation on catchment sides (some of them being progressively abandoned at the highest limits), catchment heads, interfluve and shoulders, is characterized by sloping terraces. Cultivation on the catchment floor and outlet is on levelled terraces.

In terms of limiting factors, the diagnosis is as follows: (i) in the worst cases, two or three morphological constraints (outcrops, slope, soil thickness) could be associated with two or three physico-chemical constraints (low pH, organic content and CEC), (ii) for other positions, constraints are mainly morphological and stoniness is only considered in certain positions, (iii) in certain flat positions and concave positions, limiting factors are more locally specific, but could also be morphological (except outcrops) and/or physico-chemical, (iv) but in the lowest flat positions, there are no identified limiting factors.

The highest fresh weights of maize are obtained from the most fertile plots (1.8-2.0 kg/m2/yr) and the lowest from the least fertile plots (0.2-0.6 kg/m2/yr); some compensation factors, such as distance from village for manure inputs and strategies dictated by family specificities, can explain intermediate and contradictory diagnoses.

An assessment, based on the Universal Soil Loss Equation, shows that sheet erosion is very high and above the commonly admitted limit. A quantitative simulation of the effectiveness of anti-erosion practices, carried out on 3 representative slopes, has shown that tree planting and mulching would significantly reduce soil loss, but also that other anti-erosive management options, such as diversion channels, gully stabilisation, grass strips, etc. are still necessary in some places.

Linear erosion is mainly due to runoff concentration in channels dug to evacuate excess water from cultivated fields, but with inappropriate sizing. A second cause of runoff increase and rill formation is due to bare soil compaction along paths. Mass movement and particularly soil collapse can be observed mainly on steep slopes on shale or on residual clayey material.

Conclusion
The soils are essentially colluvial in nature. The upper catchment would be continually subject to mass movement further down slope and any weathering mantle that does form here would be subject to this movement and tend to accumulate in the middle and lower catchment.
However, a red clayey material with some hematite, kaolinite and gibbsite is trapped in a paleokarst attesting previous weathering episodes in warmer climatic conditions and makes us hesitate between a Luvisol (Siltic, Rhodic) and a Thaptoluvic Regosol.

Consequently, the results of the main experiment conducted on this red soil cannot be applied uncritically to soils developed on shale and sandstone, neither to other red soils areas of Southern China.

All the data gained were synthesised in the table-legend of a geomorphopedological map. This legend presents line by line the mapping units and column by column the most discriminating arguments that justify and characterize these units. Fields arguments concern the physiography, lithology, land form, land cover and soil morphology, laboratory arguments correspond to the mineralogical and physico-chemical results of soil pit and composite topsoil samples. Limiting factors are suggested and yield of corncob fresh weight of reference plots ensures a link with (socio-economic) data as gained at a farmer level.

This legend therefore provides for this (relatively) unsurveyed mountainous area a good minimum data set for the main soil characteristics and the topsoil fertility state. The fact that references to a soil pit and/or an augering and/or a soil fertility evaluation plot are given, make this legend a good basis to build a local land information system, initiate a strategy of personalized advice and agro-environmental monitoring and finally, encourage participation in land use planning.

This contribution reaches the specific objectives fixed as a first work package in a more EU ambitious project and also offers an opportunity to make Chinese colleagues and practitioners aware of an operational methodology (Bock 2002) and its associated technologies (field techniques, DGPS, remote sensing, soil laboratory analysis, GIS).

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