The Challenge

Over the last decade, agricultural practices have been rapidly intensified in the tropical and sub-tropical mountainous areas of Vietnam as a result of demographic pressure, improved market access and increased demand for animal feed. Traditional agriculture, which combined shifting cultivation on steep upland slopes with rain-fed permanent rice cultivation in lowlands, has transformed into a more continuous monocropping system of maize and cassava (cash crops) in the uplands and irrigated rice paddies (staple food) in the lowlands. In particular the high demand for animal feed, due to a change from a vegetable to a more meat based diet, has provided a lucrative earning opportunity for farmers and fuelled rapid deforestation of uplands even on extremely steep slopes (up to 45°). In addition, the traditional moderate soil preparation in combination with maize planting with sticks has been replaced with more intensive cultivation with tillage up to three times per year to provide a weed free and appropriate seed bed for the new hybrid varieties. Such intensive upland cultivation makes these areas prone to erosion particularly during the early spring season when soils are still bare. Thus, large amounts of topsoil are eroded annually removing also soil nutrients and organic matter, thus affecting soil quality in the uplands and hence also water and fertiliser use efficiency. Increasing amounts of fertiliser are therefore needed to counteract the increasing soil degradation in the uplands of Vietnam. However, erosion not only affects uplands, but also simultaneously influences paddy yields in the lowlands by silting up irrigation reservoirs and by delivering often coarse sediments during typhoon events that can smother the rice plants and potentially influence water quality from the whole upland-paddy catchment.

The Project

Through an IAEA coordinated research project linked to the German-funded research program (SFB 564) entitled “Sustainable Land Use and Rural Development in Mountainous Regions of Southeast Asia”, the IAEA is working with the Center for Agricultural Research and Ecological Studies (CARES) of Hanoi University of Agriculture (Vietnam) and the Institute of Plant Production and Agroecology in the Tropics and Subtropics of the University of Hohenheim, Germany. The project uses stable isotopic techniques to identify hot spots of land degradation in the steep cultivated uplands of Chieng Khoi, Son La Province, in north-western Vietnam. The research consortium traces and quantifies sediment-associated organic carbon and total nitrogen fluxes in runoff water from the uplands, and assesses whether associated sediment deposition alters soil quality and crop performance along paddy rice terraces in the lowlands.

The use of Compound-Specific Stable Isotope (CSSI) techniques enabled the identification of the hot spots of land degradation in this region, and showed maize/cassava fields on steep slopes to be the main contributors, with soil erosion rates reaching up to 61 tonnes/ha/year on the steepest slopes. This erosion influenced rice production in the lowlands that was strongly linked to changes in soil fertility due to deposition of sediments delivered by irrigation- and runoff water. Eroded soils from the uplands are also a source of soil carbon and enhanced nitrogen fertility in the topsoil of lowland paddies. However, although the δ15N signatures in rice plants indicated that...
this can be a source of nitrogen uptake for rice, grain yields were not always found to be significantly influenced by such nitrogen inputs, probably due to the smothering effects that the deposition of coarse sand from eroded soils had on the rice plants. The use of $^{13}$C stable isotopes showed that grain yields along the cascades of rice paddies were often also influenced by the non-uniform pattern of water availability, with the highest water shortage being located at the bottom of the cascades of paddies.

**The Technology**

The Compound Specific Stable Isotope (CSSI) technique relies on the individual, naturally abundant isotopic ratio ($\delta^{13}$C) of marker compounds, such as plant derived fatty acids in the soil profile. By comparing the isotopic carbon signal of marker compounds in deposited soil in the lowland with the signal of the same marker compounds from reference soils in the uplands, the contribution of different land use practices in the uplands to sediment deposition in lowland paddies and irrigation reservoirs can be estimated. In addition to providing information on hot spots of land degradation the CSSI technique also allows the characterisation of upland-lowland soil organic carbon dynamics and nutrient flow linkages. The CSSI technique has the advantage of identifying hot spots of land degradation at an area-wide scale by sampling deposited soil in the lowland and reference soils from the upland in one single visit, whereas traditional ways to assess hot spots of land degradation are mostly plot specific, time intensive and costly. The CSSI technique is supported by natural abundance stable isotope methods, such as $^{15}$N and $^{13}$C stable isotope compositions of crops to provide comprehensive information on the impacts of integrated land use management on the overall water quantity and quality.

**The Impact**

This project highlights the importance of linking upland and lowland agricultural practices. Lowland paddy production depends on water runoff from uplands. This runoff, however, must be effectively managed so that losses of top soils and nutrients, that would otherwise reduce upland crop productivity, are controlled. At the same time the lowland paddy rice will benefit from the water and nutrient from uplands without the smothering effects of coarse sands. The project shows that mulch-based no-till farming systems on the uplands can achieve this goal. A similar study in the uplands of Thailand, in the context of SFB 564, proved that, over a period of 3 years, minimum tillage and mulching reduced erosion from 24.5 to 2.5 ton/ha while runoff decreased only moderately from 866 to 427 m³/ha whereas contour hedgerows impeded the flow of water too much, to 187 m³/ha. The application of minimum tillage and mulching therefore shows great potential for the intensification of agriculture in the mountainous regions of Vietnam and of South East Asia in general, as it enables a reduction of erosion without hampering the availability of water so important to downstream rice farmers. The increased interest in animal fodder for ruminants also opens up the opportunity to introduce these crops to the steep upland slopes. The findings of this project have been used to raise the awareness of farmers and to assist them in adopting strategies to mitigate the impact of typhoons in north-western Vietnam. The willingness of farmers to adopt such strategies was influenced by the experienced economic impact of flooding and water management failures at the household level and an understanding of the linkage between upland and lowland agricultural practices. Successful implementation of soil conservation measures will therefore depend on the ability of local policy makers to raise farmer awareness and to provide appropriate incentives.

For further information, please visit:
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