APRIL 2020 **#4**

Cusiana watershed lower forest zone: Left: Extended grazing, degraded riparian forests and severe riverbed erosion. Right: Intact riparian zone and contour forest strips. (Photo Hanspeter Liniger)

SLM POLICY BRIEF

Land Use Change Impacts in the Cusiana Watershed of the River Basin, Orinoco River Basin, Colombia

In large and complex watersheds with different agro-ecological zones such as the Cusiana watershed in Colombia, there are many unanswered questions relating to changes in river flows and river channel dynamics. People observe dramatic changes in river flows with floods, flashy peaks, lower dry season flows restricting navigation, changes in river course and riverbank erosion. So far, there is no evidence on substantial change in rainfall. Furthermore, land management and land use change and their impacts onsite and offsite are difficult to assess and therefore seldom understood, or simply ignored. For the Cusiana watershed, there is evidence, based on preliminary investigations, that land use and management changes (e.g. converting forest to grazing land) are impacting river flow. There is urgent need for further data and analysis on specific offsite impacts land management changes (e.g. promoting riparian forest buffers or productive and protective land management) in all zones – and their cumulative impact.

COLOMBIA

Key message

- The diversity and complexity of each agro-ecological zone, as well as the entire watershed, must be considered to understand the impacts of and implications for land management.
- Riparian forests must be protected, maintained and restored within the entire watershed to reduce onsite degradation, buffer inflow, and regulate sediment and water flow to downstream areas.
- Expanses of the cloud forest zone converted to intensive grazing are a hotspot for degradation and thus sustainable land management. This means no further deforestation and improved grazing management systems.
- Further hotspots are areas under oil palm and rice - which are replacing rangeland floodplains and swamps. Emphasis required here is agroforestry, improved rangeland management, and product labelling and marketing.
- Robust data on specific off-site impacts, and their sum within large watersheds are needed, to provide hard evidence regarding riverbed mining, oil extraction and swamp drainage.

Too much water – too little water

The Cusiana watershed (5,000 km²) is part of the Orinoco river watershed (see cover photo), which is a global outstanding ecoregion due to its biological singularity[5]. In the past few years, the Cusiana river has undergone changes. Torrential rainfall and violent floods with high peaks are causing damage to infrastructure (e.g. the main road) and the riparian zone, especially in the rainy season. In the sub-Andean zone with its steep topography, the unprotected banks of the Cusiana river are being undermined, and as a result landslides and mass movement have increased1. In the foothills, land users claim that they are losing land - and their access to land - due to changes in the river course. Furthermore, they assert that, after torrential rains and subsequent floods, dry season river flow is decreasing in the entire watershed. In the lower zones of the watershed also, the rainy season base flow is reported by land users and experts to be decreasing. Although local people note a decrease in high and long-lasting floods, they observe that the peak floods come, and retreat, more rapidly. Combined with the lower dry season flow, this means that the traditional boat transport for people and goods is hampered, and further more bio-diversity may be affected (e.g. fish communities).

Main land use and land cover changes over the last decades

The Llanos Orientales, the Colombian side of the Orinoco watershed, has undergone major land use and land cover changes (LULCC) over recent decades, so has the Cusiana watershed. Páramo zone: The Páramo located at the highest altitude, occupies about 5% of the watershed. The land is partly used for extensive grazing of sheep and cattle, and over the last decades use has only changed moderately.

Cloud forests: The cloud forest zone (both upper and lower) representing about 30% of the watershed, is the zone with the highest rainfall (with rainfall reaching 3000 mm or even above 4000 mm per year, depending on altitude). The mountainous topography is steep and geologically highly unstable. The upper cloud forest zone is mainly untouched, especially on its steep slopes. However in the lower cloud forest zone, the natural forests are being converted to grazing land especially in the more accessible areas, close to the main road, and on the more gentle slopes.

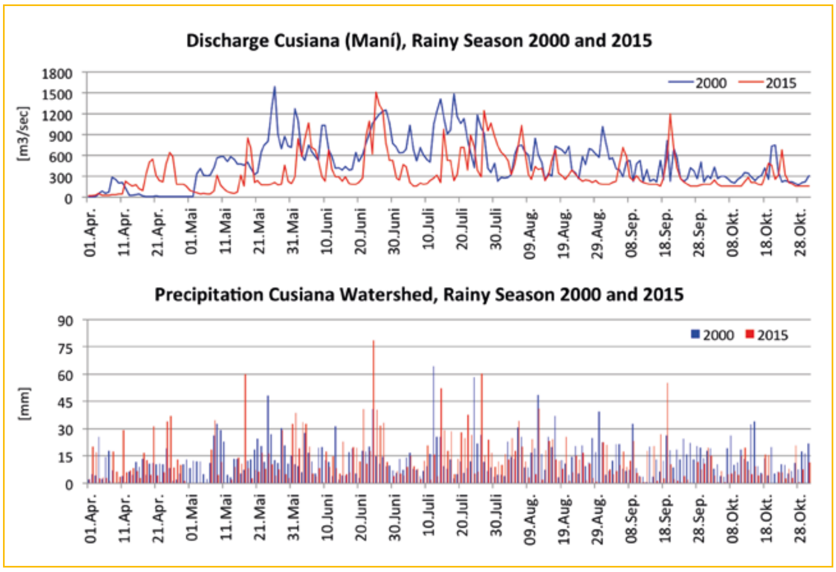


Figure 1. Cusiana watershed rainfall and discharge towards the lower end of the floodable savannah: Comparison of 2000 and 2005. Source: IDEAM

BOX 1: Definitions

Onsite: locations where the land management practices are applied.

Offsite: area where land management applied somewhere else have an impact on land and people.

Riparian forest: "A riparian forest buffer is an area adjacent to a stream, lake, or wetland that contains a combination of trees, shrubs, and/or other perennial plants and is managed differently from the surrounding landscape, primarily to provide conservation benefits. Riparian buffers can also be managed to include trees and shrubs that produce a harvestable crop along with the conservation benefits".[6]

Foothills: The foothill zone, comprising 25% of the watershed, is the natural transition from the cloud forests in the mountains to gallery forests along the rivers with grassland in the open savannahs. This zone has experienced the most extended LULCC, triggered by the economic boost driven itself by oil extraction, the petroleum industry and the construction of the main road, 'Carretera del Cusiana', connecting the Orinoquia region with Bogotá. The subsequent immigration wave increased the population density from 8 per km² in 1973 to 70 people per km² in 2005[1] and led to an agricultural expansion (oil palm, rice, pineapple and cacao) and increasing land claims by oil and mining companies.

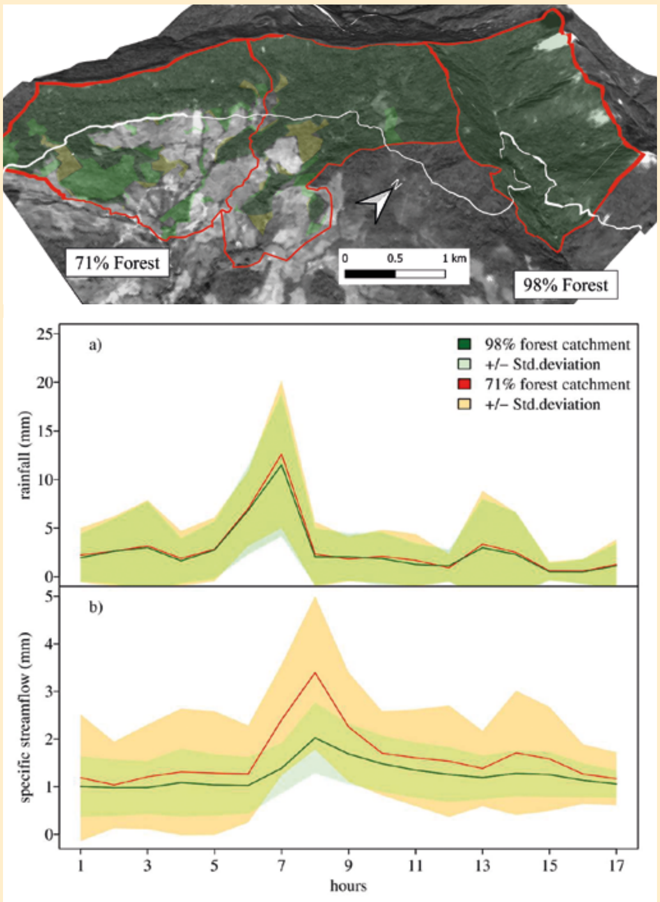
Seasonally flooded savannah: These flat lowlands, representing 40% of the watershed, are poorly drained and provide flood ponding during the rainy season. The savannah have been seen as the last agricultural frontier in Colombia for extension of agro-industrial crops such as oil palm tree, which now is more than seven times higher than its extent in 2007. The savannah have been seen as the last agricultural frontier in Colombia for extension of agro-industrial crops such as oil palm tree, which now is more than seven times higher than its extent in 2007.

Assessing offsite impacts of land management

This wide range of land use and management regimes generate a variety of on- and offsite impacts in each agro-ecological zones, from the Andean mountains to the Orinoco lowlands (Box3), and over the entire watershed (Fig. 1). With respect to the claims of the local land users and experts regarding the river flow, data analysis reveals that despite the annual rainfall being only 10% less in 2015 than in 2000, the total discharge measured was reduced by almost 23%. Starting from early May until end of July the 2015 discharge was almost continuously and clearly below the discharge recorded in 2000 (-41%), even though the amount of rainfall during the period till end of July was about the same (+5%). Up to now, no plausible explanation has been found for the decreasing discharge. Since the seasonally flooded savannahs are being drained for oil palm cultivation, this theoretically would mean more discharge. Uncertainties remain about the data itself, and specifically calibration of the water levels and discharge volume due to possible changes in the cross section of the river at the calibration point – where the riverbed has widened.

A close analysis of the data shows that the peak-discharge of the five highest rainfall events in each year occurs 1-5 days after the peak rainfall in 2000, but in 2015 the flashy peaks always occur within one day, indicating a faster reaction time due to accelerated runoff and river flow.

BOX 2: Rainfall and runoff contribution in two catchments: one entirely forested and one partly converted to grazing land



Comparison of rainfall and streamflow in two neighbouring catchments, one with 98% forest, and the other with 71% forest and 29% mostly grazing land in the cloud forest zone of the Cusiana watershed, Chameza region. (Source: Beatriz Ramírez)

For the same rainfall in the two catchments, the peak flow of the 71% forest catchment is more that two thirds higher than the 98% forest catchment. One hour after the peak flow the flow is almost the same in both catchments until seven hours after the peak. However, at the beginning of the dry season the 98% forest catchment releases the extra water stored during the peak flows and the streamflow (discharge) is about one third more over 1-2 month. Even afterwards the 98% forest catchment produces more water and releases it especially during rainfall events in the dry season.

Considering that less than one third of the catchment has been converted to grazing land, this is already a very clear indication of the strong impact of land use change. It is interesting that the response time of both catchments is the same: this could be explained by the fact that the riparian zone in the partly deforested catchment has not been cut and thus still buffers the speed of channel flow. Given the insights gained through the monitoring of catchments a modeling approach would reveal the extent of further increase of the peak flows and the total recharge if the catchments were further deforested and converted to grazing lands.

Catchment with 71% forest cover (3.7 km^2; 1575-2241 m a.s.l.; 18% slope). (Photo Hanspeter Liniger)

Catchment with 98% forest cover (3.0 km^2; 1668–2490 m a.s.l.; 26% slope) in Chameza region, Cusiana Basin. (Photo Hanspeter Liniger)

Improving land and watershed management and their impacts

Each intervention has specific on-and offsite impacts, which are challenging to quantify. Furthermore, the combination of different practices has an overall amplifying or buffering effect, which makes it even harder to assess and to quantify.

Preserve, maintain, and restore riparian forests: Although documentation of riparian forest management (perennial, protective and productive) and their offsite impacts remain rare, the protective function of riparian forests against riverbank erosion and damage during floods is well known[2,3]. There is no healthy river without protective riparian zone and stable riverbeds, particularly in tropical watersheds with steep topography, torrential rains and high river flows (see Box 2). Ignoring the benefits of riparian forest buffer strips, land users in the lower zones of the Cusiana watershed often extend their plantations to the river edge because these buffer zones (Fig. 3) provide fertile land that is economically valuable, on-site, for agriculture. However, there is scientific evidence that the accumulated overall economic losses, on-site and off-site combined, are higher when the riparian forest is removed than when it is left intact, and thus riparian forest buffers can secure productivity of floodplain plantations over the average lifetime of an oil palm plantation[2]. Moreover, riparian forests along all small and large rivers from the high- and lowlands and the floodable savannah have the potential to buffer and mitigate damaging peak floods and to make available harvested floodwater during the dry seasons. They also contribute to reducing contamination, pollution and sediment loads. Thus, any change to these ecosystems and their functions has serious impacts on downstream population and ecosystems.

Forest and grassland mosaic in the cloud forest zone: There are options for sustainable grassland management even on steep mountain zones, as long as there are no extended areas of deforested land. Good grassland management practices maintain

Figure 2. Land uses and ecosystems in Cusiana watershed: Paramo, Upper and Lower Cloud Forest, Foothill, and floodable Savannah. (Source: Diego Orduz, Luisa Vega, Photos: Hanspeter Liniger)
Sustainable Land Management: Conserving gallery forests, a large extent of cloud forests. Developing agroforestry, silvopastoral production systems in the mountains, traditional livestock and other productive systems do not affect high wet season flows (flood pulse), sustained dry season flows and cloud formation in dry season.
Land Use Change: forest degradation, extension for grazing in the mountains, irrigation and drainage (rice, oil palm) in savannahs increase floods, reduce low flows. In dry season, evapotranspiration, cloud formation and rains in the cloud forest is reduced.

a mosaic of grassland, forests and riparian forests. On very steep slopes with geologically weak stability, additional structural measures may be needed (e.g. using bioengineering techniques[4]). Furthermore, the extension of practices involving other non-timber forest products such as honey/beekeeping, highland shade-grown coffee as well as fruits and vegetables in agroforestry home gardens have potential for complementary income.

Land management in the foothill and flooded savannahs: In terms of sustainability and changing the function of floodable savannah, large-scale oil palm and rice plantations remain problematic. The major problem is related to the large-scale drainage of the savannah, which affects the regional hydrology. For oil palm, floodable lands and depressions ought to be avoided. Limitation of the plantations to slightly elevated or sloping land should be considered, where there is no need for drainage (e.g. the foothill zone). Agro-silvo-pastoral systems combining oil palm plantations (including riparian forest buffer zones) with domestic native plants with economic potential (e.g. the moriche palm, *Mauritia flexuosa*, which produces a very nutritious oily fruit used by Orinoco indigenous communities) and domesticated animals adapted to the marked savannah seasonality such as the capybara (*Hydrochoerus hydrochaeris*) or the yacare caiman (*Caiman yacare*), which can be used for meat and leather. Large-scale rice cultivation requires extended irrigation and drainage systems, which interfere with the function of natural wetlands and floodable savannah. The potential for further expansion of rice cultivation is limited. In terms of sustainability and maintaining the ecosystem and its biodiversity and functions, the extensive non-irrigated rangeland management that has developed over the last decades is still the most appropriate land use practice for this sensitive agro-ecological zone. Furthermore, improvements in income through value addition to products (e.g. product labelling and marketing) as well as eco-tourism can be further explored and developed.

Required knowledge and data

To promote appropriate sustainable land management (SLM) within sustainable watershed management, gaining clarity over the specific and combined on- and offsite benefits is a must. Moreover, the complexity of interventions and considerations grows exponentially along with the extent of the watershed.

In the Cusiana watershed, basic long-term data on rainfall, riverflow, peak floods, springflow, and the spread and impact of land management practices on water, food security and human well-being remains a central challenge that needs to be addressed for developing watershed plans, identifying appropriate SLM practices, and assessing the on- and offsite impacts of interventions. Lack of these monitoring systems is

BOX 3: Major on- and offsite impacts of current land management

Zone	Onsite impacts	Offsite impacts
Lower Cloud Forests	• Instability of slopes due to LULCC from forest to grassland • Instability of riverbanks due to deforestation of riparian forest	• Flood events and deposition of sediment from inflow are pushing the Cusaina river to the opposite bank causing accelerated riverbank erosion, and decreased slope stability. • The LULCC from forest to grassland increases runoff, hence the flood risk downstream • Lower dry season flow due to accelerated runoff, decreased infiltration and water storage capacity by soil loss during rains
Foothills	• Loss of buffer strip/ riparian forest due to cultivation up to the edge of the riverbank enhancing riverbank erosion and loss of arable land • Mining of alluvial material, which contributes to river bed changes due to the removal of sediment material	• Siltation and filling up of riverbed downstream due to eroded material • Increased runoff due to LULCC • Reduced dry season flow due to crop irrigation and soil degradation
Flooded Savannah	• Loss of buffer strip/ riparian forest due to cultivation up to the edge of the riverbank enhancing riverbank erosion and loss of arable land • Disruption of the natural hydrological regime of wetlands due to irrigation and drainage systems • Drying up of the floodable savannah and the wetland (reduced flood water storage and retention capacity) • Loss of wetland ecosystems and biodiversity • Loss of the wetland's water filtering and purifying capacity • Release of soil organic carbon into the atmosphere	• Peak flow with accelerated recession • Reduced dry season flow due to crop irrigation • Filling up riverbed and clogging the river channel downstream due to eroded material • Decreasing water quality • Increasing temperature of the environment due to loss of temperature regulation capacity of wetlands • Reduced evapotranspiration due to drying up of wetlands, thus, reduced available moisture carried back towards the Andes by trade wind systems resulting in less cloud formation and less rainfall (see Figure 2).

constraining research into the complex interactions between land management practices and impacts on productivity, degradation and hydrology. Constrained research means ill-informed decision-making and implementation. Understanding the hydrological processes related to land use and management in large watersheds with sensitive agro-ecological zones will ensure that future sustainable resource management strategies can effectively mitigate flood peaks, dry season flows, drying up of wetlands and floodable savannah and enhance the resilience of land and people.

In terms of investigating observed changes or river flows and water quality, large-scale watersheds pose an enormous challenge in identifying degradation hotspots, the causes of these, and quantification of the cumulative impact land use and land management change. A unique nested approach within the cloud forest zone reveals the impacts of land use change on runoff (see Box 2). To investigate impacts of land use change and land management practices on river flows (incl. floods and dry season flows), sediment loads and water quality in each zone, and in order to assess different scenarios of land use change and land management options all over the large watershed, there is need for further nested approaches monitoring representative catchments and their use. This would reveal the needed evidence for decision-making and promotion of sustainable land management practices.

The involvement of research and continuous monitoring is essential to support policy formulation and large-scale intervention project. While the need for research should not stop investment in sustainable land management, investigations and monitoring has to be continued throughout any intervention phase - and also far beyond - to insure that intended impacts are achieved.

Figure 3. Increased floods as a result of upland land use change impact on the lowlands. Left: Intact riparian forest minimizes riverbank erosion: despite being steep in some places, the river bank is not undercut. Right: Without riparian forest, the riverbank is severely eroded and undercut. Each event removes more of the bank, and widens the bed. During the dry season, the water is shallow - spreading over the wide riverbed. (Photos: Hanspeter Liniger)

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Implications for practice, policy and research

It is important to acknowledge the complexity and diversity of on- and offsite impacts in each ecosystem and agro-ecological zone (ranging from Andean Páramo at 4000 m a.s.l. to savannah lowlands at 200 m a.s.l.) and their buffering and amplifying effects within large watersheds. In view of amplifying offsite impacts in lower zones of the large watershed, several diversified sustainable land management interventions in hotspot areas need to be considered to achieve the intended impact.

Hotspots of degradation over the entire watershed are riparian forests. Their on- and off site benefits must be recognized, and they must be protected, maintained and restored along all watercourses – from small streams to large rivers - in order to ensure their buffering function on runoff in order to reduce landslides, riverbank erosion, and sediment loads downstream.

An additional hotspot for sustainable land management implementation is in the lower cloud forest zone, with extended areas of steep land used exclusively for intensive grazing. Further extension of deforested areas has to be limited and alternative grazing land options need to be identified, developed and implemented; for example disaggregating grazing land into a mosaic with protective forests.

Hotspots in the savannah lowlands are land use changes involving extended drainage of floodable savannah areas and swamps for large-scale oil palm cultivation. The further extension of this intensified land use has to be assessed carefully. Alternative management involving agroforestry and rangeland management options as well as product marketing and tourism should to be promoted.

Robust data on off-site impacts and their sum throughout the watershed are needed to provide evidence for decision-making. As a basis for evidence-based decision-making, there is need for further nested approaches – monitoring representative catchments all over the large watershed as well as the watershed as a whole – in order to identify impacts of land use change and land management practices on river flows (incl. floods and dry season flows), sediment loads and water quality. Various claims regarding negative impacts of riverbed mining and oil extraction impacting river flows and river behaviour need to be proven scientifically. Furthermore, the impact of swamp drainage and reduction of evapotranspiration in the dry season on cloud formation and rainfall in the upstream area needs to be clarified.

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Further information

Link to all results from 'on- and offsite benefits of SLM':

- SLM Policy Briefs: www.wocat.net\ …
- Synthesis Report: www.wocat.net\ …
- Videos: www.wocat.net\ …
- Land management practices: WOCAT SLM Technology and Approaches database: www.wocat.net\ …

Ramírez, B.H., M. van der Ploeg, A.J. Teuling, L. Ganzeveld, R. Leemans (2017). Tropical Montane Cloud Forests in the Orinoco river basin: The role of soil organic layers in water storage and release. Geoderma 298 (14-26).

1 – 6 The list of references is available in the online version of this policy brief: www.wocat.net

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