Watershed Inventory Siem Reap, Cambodia:
A Combination of Social and Natural Science Methods

Harald Kirsch

Source: MRC-GTZ WSMP

Sand mining upstream of Phum Khlat

Abstract: The population in the Stung Siem Reap Watershed in Northern Cambodia is suffering from the declining quality and quantity of their water resources. A Watershed Inventory was undertaken to identify the main causes and to provide local planners with comprehensive information on watershed issues, including land use changes and their consequences. Hereby the combined application of environmental, hydrological, and so-cioeconomic survey methods – supported by GIS application - proofed to be successful to detect sand excavations from riverbanks and the continuous depletion of forests as having a major negative impact on water resources. This methodology also helped to explain upstream – downstream re-lationships and climate-related phenomena like floods and droughts. To ensure a more sustainable development in the future, the main objective of all actions must be to stop the severe destruction of the natural resources, which has foreseeable consequences for the socio-economic system of the watershed.

Keywords: Watershed; Siem Reap; Cambodia; Land Use; Natural Resources; Hydrology

Watersheds are spatial units defined by natural boundaries, the watershed divides. They consist of socio-economic as well as bio-physical elements with a high grade of interdependency. Manipulations of the waterways and their surrounding land have deep impacts on the functionally of watershed elements and can eventually contribute to the breakdown of societies such the historic Khmer Empire of Angkor (KUMMU 2003, LUSTIG et al. 2008). This paper describes the combination of social and natural science to identify modern days' watershed characteristics and issues in the same area in Cambodia.

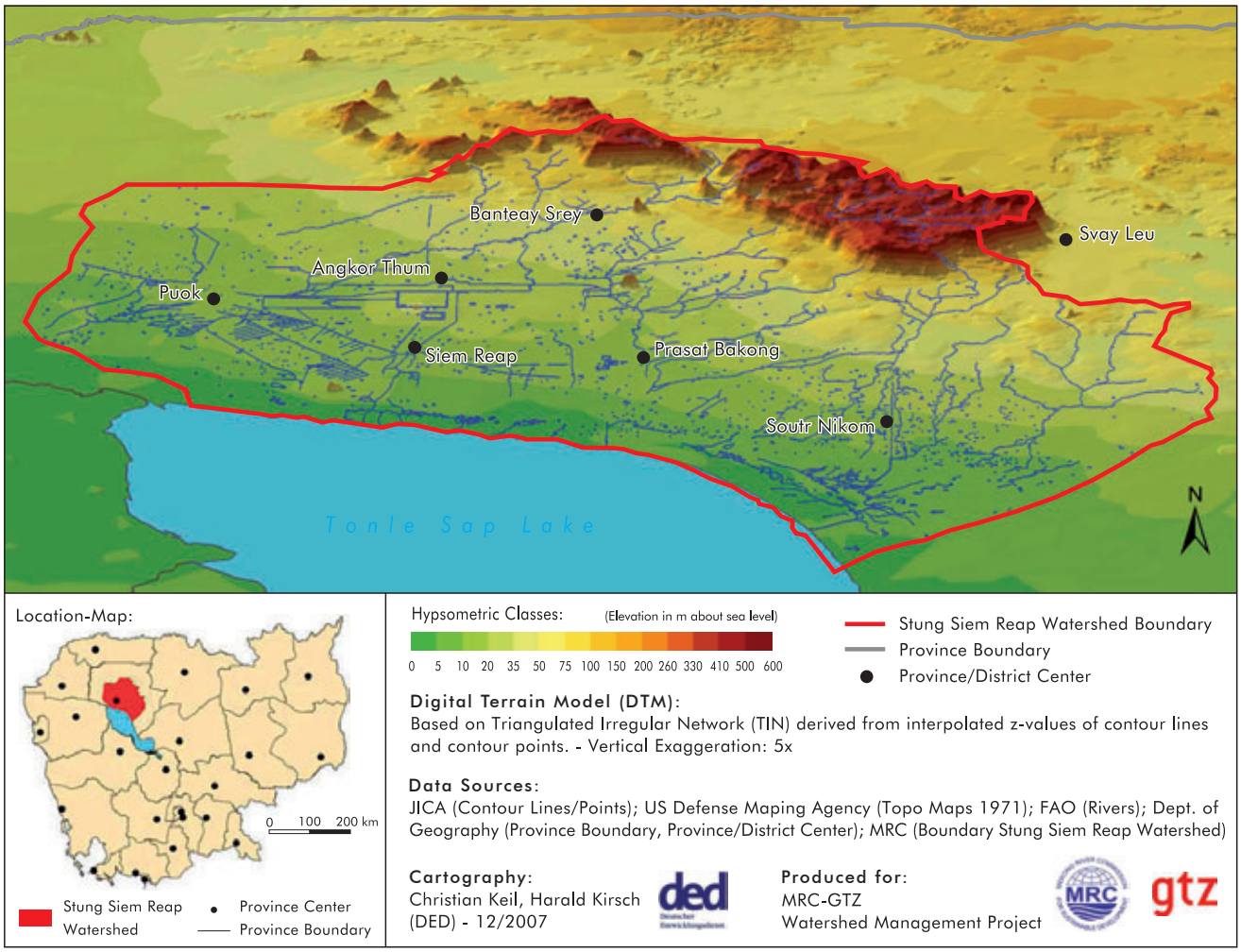
Background

The MRC-GTZ Watershed Management Project (WSMP)[1] conducted a first baseline survey in the Stung Siem Reap Watershed in September 2004 to compile data and information on socio-economy, land use, and natural resources management for impact monitoring and identification of interventions (SCHINDELE et al. 2004). To provide local planners and the Cambodian National Working Group on Watershed Management with a comprehensive database for the identification of actual watershed issues, and to gain more insight in environmental, hydrological, and socioeconomic settings and their changes during the past years, the 2004 watershed baseline survey had to be reviewed and updated. A multidisciplinary team of MRC-GTZ WSMP conducted this update in April and May 2008. The core team consisted of four Cambodian subject matter specialists and one international expert. The focus was laid on water-related issues - including local knowledge and wisdom - concerning the Stung Siem Reap River itself as well as other waters and streams in the watershed (KIRSCH et al. 2008).

Methodology and Approach

Data were gathered on two levels: primary data collected in the field (local knowledge survey, rapid stream assessment, geology and soils) and secondary data collected from various organizations, institutions and project reports (commune and village statistics, community managed and protected areas, hydrological and climatological data, information on land mines, and Agro Ecosystem Analyses). Furthermore, several relevant studies, e.g. on climate change (WSMP 2008), environmental impacts of stream diversions (KUMMU 2003; LUSTIG et al. 2008), integrated planning (JICA 2006), and groundwater (JICA 2006; GARAMI & KERTAI 1993; JSA 1996) were analysed.

Additional up-to-date information on stakeholders and water resources-related issues and problems were gathered during a workshop-style 2½ days WSM training course for district and commune representatives in April 2008. The results of PRA (Participatory Rural Appraisal) and environmental surveys conducted in 3 villages during the WSM Planning Training in February 2008 were also considered.



Pacific News Cartography: © Claus Carstens 2010

Fig. 1: Digital Terrain Model of the Stung Siem Reap Watershed

Already existing digital data on topography, geology, soils, and land use were analysed to evaluate their usability and then further processed. An interpretation of a 2005 SPOT[2] satellite image, combined with GPS coordinates of ground surveys, produced a detailed land use map.

All data with a spatial reference were added into a GIS-based database[3]. This enables the WSMP staff to provide needs-tailored information by combining various GIS layers and data sets on any desired scale to support decision-making, planning and implementation by local government authorities and the Siem Reap Watershed Committee[4].

Identification and location of the Siem Reap study area

The watershed investigated is located in north-western Cambodia in the province of Siem Reap, home to the world-famous historic temple of Angkor Wat. It comprises an area of 3,619 sqkm and extends from the mountain range of Phnum Kulen to the Tonle Sap Lake (Fig. 1). The elevations in the upstream area of Phnum Kulen reach up to 500 m asl, whereas the town of Siem Reap in the downstream area is located only at 15 m asl.

The watershed overlaps with 10 districts having totally 66 communes completely or partly in the watershed

Source: Harald Kirsch

Forest depletion at the northern slope of Phnum Kulen between Oct. 2003 (l) and Apr. 2008 (r)

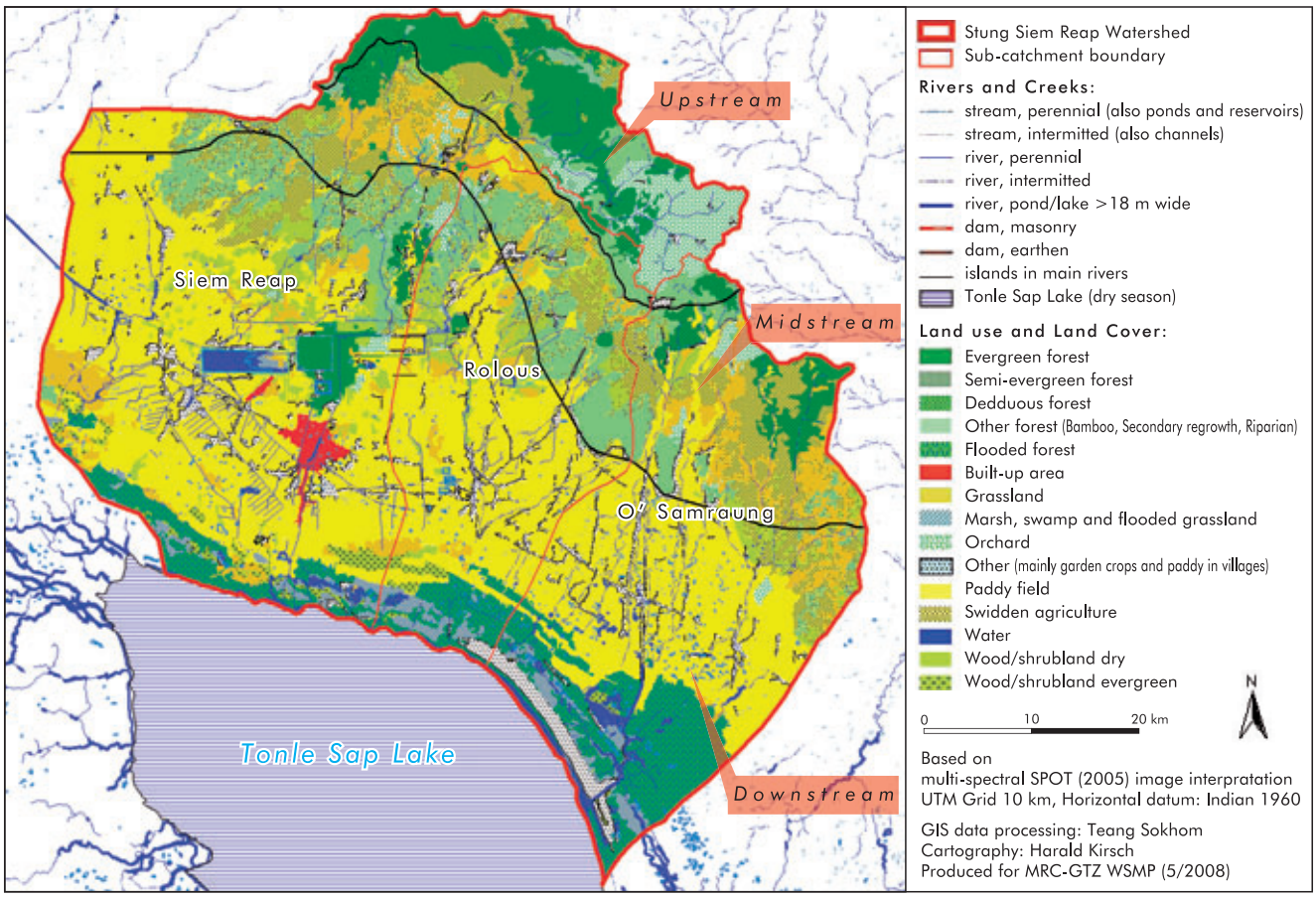


Fig. 2: Land Use Map of Stung Siem Reap Watershed

area. There are around 470 villages within the watershed with a total population of ca. 500,000. The annual growth rate is about 2.2%. The majority of the people live in a ca. 30 km wide strip between the foot slope of Phnum Kulen and shoreline of the Tonle Sap Lake (Commune Statistics 2002-2003, 2007). Siem Reap is one of Cambodia's poorest provinces with limited access to basic education and health services. Malnutrition is still widespread.

Based on hydrology and topography, the watershed has been subdivided into the 3 sub-catchments: Stung Siem Reap, Stung Roluos, and O' Samraung (Fig. 2). Furthermore, the whole watershed (incl. the sub-catchments) was subdivided into 3 major landscape units (KIRSCH et al. 2008): 1) The Phnum Kulen sandstone plateau is defining almost the entire upstream area of the watershed; 2) The undulating midstream area with a complex geology (volcanic rocks, sandstone, and sandy sediments with laterite) extends 10-20 km from the foot slope of Phnum Kulen towards SW; 3) The flat downstream area is located on alluvial fans which stretch with 0-2% inclination towards SW until the Tonle Sap Lake.

Sandy sediments are functioning as groundwater aquifer. The soils in the watershed reflect the geological setup, the topography and the influence of surface water and ground water. Most soils have been classified as varieties of Arenosols (FAO 2006). These are sandy soils with low clay content and low water-holding capacity. All Arenosols in the watershed are weakly consolidated and thus prone to erosion.

Vegetation & Land Use

The spatial distribution of vegetation types (evergreen vs. deciduous forest) in Siem Reap reflects the available water either through precipitation or soil- and groundwater. Satellite image analysis revealed that between 1993 and 2005 almost 50% of the forest (30,000 ha) was converted into non-forest, predominantly into slash and burn areas. This occurred mainly in the upstream and upper midstream areas. Most changes of forest cover were from evergreen forest into non-forest. On the whole, forest cover decreased from 14% to 6% during the specified period.

Illegal logging at a big scale is organised by powerful and influential persons. The survey indicated the likely involvement of the military, police and politicians. On the other hand there are poor farmers who are engaged in illegal logging for subsistence. Large evergreen forest areas within the Kulen National Park have been cleared since the end of 2003. Some of the depleted area has been converted into orchards, on others slash and burn is practiced; others just remain fallow and will change into shrub or grassland.

The proven huge extent of forest degradation in the watershed confirms statements made by local villagers that river flow changes in the area are caused by forest loss in the upper part of the watershed. Illegal commercial logging is still going on in Siem Reap, despite enhanced law enforcement by the Forestry Administration. As figure 2 shows, the largest proportion of the land use is still paddy fields (38.8%), followed by swidden agriculture / slash and burn (9.8%) and other forests like gallery and riparian forest, regrowth, and bamboo (10.0%).

As described by SCHINDELE et al. (2004) already, land conflicts between local people and outsiders seeking areas for commercial purposes

Stream Morphology Survey at Stung Roluos, Phum Stung

Source: Harald Kirsch

are increasing. The poor, illiterate and less educated lose in this process because they do not have the access to money and power needed to defend their rights. As a result, land is becoming progressively more concentrated in the hands of people or entities who are politically well connected or can afford informal payments, especially in regions with potential for tourism, logging, industrial or urban development. During the fieldwork the team could observe a shift from small area encroachment for subsistence farming towards larger areas being encroached and fenced.

There are three protected areas in the watershed: the above mentioned Kulen National Park, the Angkor Wat Protected Landscape with the surrounding protection zones under APSARA[5], and the Tonle Sap Biosphere Reserve. In 2008 there were 37 community forestry areas and 6 community-protected (forest) areas in the province; most of them are located within the watershed boundary.

Climate

The climate of the area investigated is determined by the Asian monsoons. The rainy season lasts from May to October (Fig. 3). The natural climatic variability is quite high; the beginning of the rainy seasons can be as much as one month too early or too late. The amount of monthly and yearly rainfall and the number of rain days can naturally vary from year to year (Siem Reap station: 1179 – 1765 mm/year, average 1420 mm; 58 – 177 days/year, average 136 days). This is causing problems for the widely practiced rain-fed agriculture. There is also a pronounced spatial variation of precipitation in the study area, caused by wind directions and orographic influence. The mean annual rainfall ranges from 1093 mm in Bantaey Srei to 1828 mm on Phum Kulen. The temperatures range between 10.7 °C (min.) in the cold season in December to 40.8 °C (max.) in April. The annual mean temperature in measured at Siem Reap station is 27.6 °C.

Villagers who were long-time residents identified in interviews certain years with droughts, prolonged intra-seasonal dry spells, and floods (YU 2008, WSMP 2008). Nowadays both phenomena seem to occur more frequent than in the past. Climate data[6] show that the reported drought years coincide with a much below average rainfall in July/August. The mentioned floods can be clearly attributed to above average rainfall at the beginning or end of the rainy season

Hydrology & Water Resources

Drainage patterns in the lower Stung Siem Reap sub-catchment are indicating that the river network has been modified. This has happened through stream diversions since the Angkor period in the 13th century (KUMMU 2003, LUSTIG et al. 2008), with consequent erosion and sedimentation changing the whole river system. Stung Roluos and O' Samraung sub-catchments are – except for some man-made interconnecting channels – still in the original stage. Their drainage patterns are common for alluvial fans or deltas. The most typical characteristic is the river dynamic caused by the power of stream flow, a low gradient long profile of streams, and the geology (weakly aggregated sandy sediments). River course changes through erosion and deposition, flooding and meandering are natural processes in this kind of landscape. More recent human interventions such as depleting the stream bank vegetation, sand mining, stream diversion, and logging have only accelerated these processes.

As a result of hundreds or even thousands of years of river course changes many ox-bows and back-swamps have developed. Today these are the hundreds of ponds and small lakes in the downstream area of the

watershed, which are an important water reserve in the dry season and source for small-scale irrigation in wet season. It is assumed that these ponds receive water through floods, rainfall and groundwater inflow. In interviews the villagers complained about decreasing dry season water levels in some ponds since several years.

The width and depth of the rivers and creeks vary within a short distance according to the riverbed characteristics, relief and geology. They are between 1.50 m to > 20 m ca. wide, and between 10 cm to almost 2 m deep (dry season). In the rainy seasons all streams in the pilot watershed flow into the Tonle Sap Lake, but since 10 years O' Samraung is completely seared in the dry seasons.

Except for two stations, no stream flow and water level data were available. Thus the team had to rely on interviews with local communities (YU 2008) and outputs of WSM trainings and workshops In almost all surveyed communities the people stated that the dry season stream water level has decreased significantly in the last 10 years, the rainy season stream flow is increasing yearly and floods come faster and are higher than before, and the flow rate of natural springs has significantly decreased during the dry seasons in areas where forests have been degraded.

The problem of extreme seasonal changes in stream water flow seems to be most severe in the downstream area, but occur as well mid- and upstream. All interview partners said that logging upstream of their community is the reason for the described problems. The local people clearly attribute that negative changes in water resources to the loss of forest (e.g. YU 2008).

The analysis of the 2005 SPOT satellite image, ground checks, and a comparison with previous spatial land cover data (1993, 1997, 2003) from MRC-GTZ, FAO, JICA and the Cambodian Forestry Administration revealed that the most extensive forest depletion took place in the upstream and upper midstream areas.

Villagers living in fishery villages along the Tonle Sap Lake shoreline complained that the annual rise of the lake water level declined from 6 m before to 2 – 4 m nowadays. This has changed fish migration pattern and negatively influences the amount of fish they can catch. For their own consumption villagers also catch fish and other aquatic animals in the canals, rivers, streams and in paddy fields in their neighbourhood. People reported that because of increasing water shortage in the dry season, fish resources have become very scarce. Migrating fish species from the Tonle Sap are declining in the rivers, they almost disappeared from up-stream but new species are spreading.

Only about 7% of the population in the pilot watershed has access to safe drinking water[7]. It comes mostly from dug wells (76%), but also from rainfall, rivers, and from natural springs.

Water quality problems are serious in Stung Siem Reap and Stung Roluos catchments. Stung Siem Reap, which leaves Phnum Kulen as a clear, clean and unpolluted river enters the Tonle Sap Lake as sewer. The reasons are the entry of wastewater, solid waste, human excrements, and agro-chemicals (JICA 2006). A lot of people suffer from skin diseases after bathing in rivers in the mid- and downstream areas and mention declining water quality over the last years (YU 2008).

Sand excavation, soil erosion from cleared land and river bank erosion lead to an increase of suspended and sediment load. GIS mapping that included information from field surveys, analysis of SPOT satellite images, and turbidity data of water samples (turbidity tube) finally proofed what previously has been stated by interviewed villagers and workshop participants: the excavation of sand for construction purposes was identified as a major reason for water pollution in the whole watershed. The mining operators showed total disregard for any law. If these practices would continue, the resulting high sediment and suspended load in the rivers will certainly have a negative impact on all kinds of water utilization. It can even lead to a breakdown of the function of water take-off channels. Reservoirs and rivers already have increasingly been silted, which caused frequent floods in the town and droughts in agricultural areas (JICA 2006).

The impact of the 2009 economic crisis on the construction business reduced the demand for sand. Aware of the results of the watershed inventory, the provincial governor issued a ban on sand mining in waterways that so far has been widely obeyed[8].

Hydromorphic soil properties and field observations in dug wells by the WSMP team led to the conclusion, that groundwater tables in the dry season are relatively shallow (up to 1.7 m below ground level) in most flat landscape units. According to JICA (2006), groundwater is easily accessible as the water table during the wet season and dry season lies between depths of 0 and 5 m below the ground level. However, groundwater is increasingly and uncontrolled pumped up in Siem Reap town by hotels, private enterprises and households. An unchecked continuation of this practice may cause groundwater declination and land subsidence in the future.

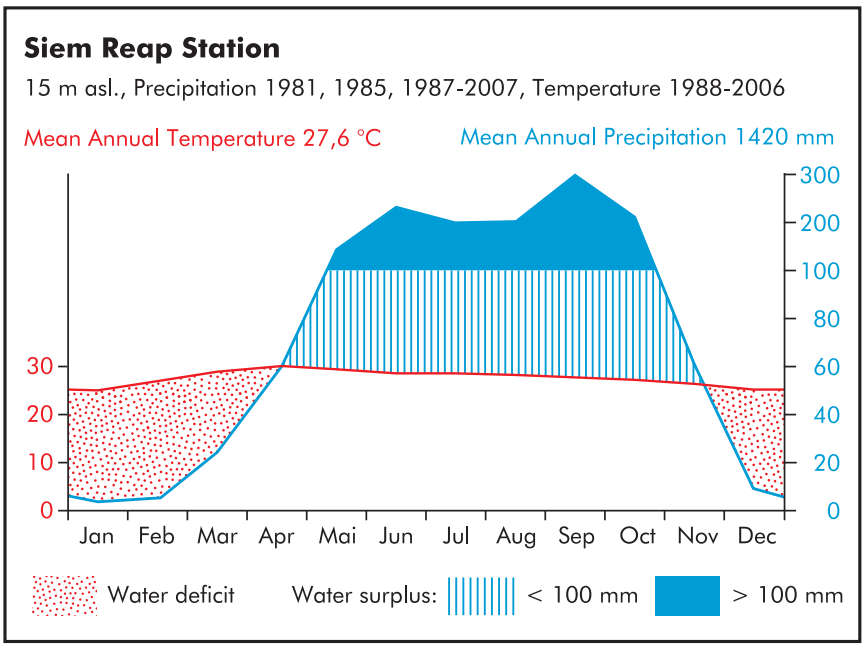


Fig. 3: Climate Diagram of Siem Reap Station

Source: Harald Kirsch

Local Knowledge Survey in Phum Stung Village

Conclusion

The land and natural resources related problems that were stated in the first baseline survey (SCHINDELE et al. 2004) still persist. A discouraging fact is that the survey team did rarely find any improvements in 2008. The situation regarding the health of the natural resources seems to be even worse than before.

The most burning issues identified are the sand excavations from riverbanks, and the proven continuous depletion of forests up- and midstream. The offenders in the first issue were private companies, whereas all levels of the society participate in illegal logging, but to a different extent. The impacts on water resources are particularly severe in mid- and downstream areas, but occur as well upstream.

From a methodological perspective of the watershed inventory, it turned out that the combined application of social science and natural science has been very complementary and fruitful. Many climate phenomena - such as floods and droughts - which were described by the villagers during the local knowledge survey can be explained with measured climate data. However, many phenomena do perfectly match with the natural variability of the climate. But there is a recent tendency that the July/August dry spells became more severe.

An encouraging outlook is the fact, that the local rural population is very much aware about the degradation of the natural resources in their area and the consequences for their livelihood.

The main objective of all actions regarding sustainable development must be to stop the severe destruction of the natural resources, and waterways in particular, that may lead to a partly collapse of the watershed services provided by the natural system with foreseeable consequences for socio-economic system of the watershed.

Endnotes

1) For more information about the MRC (Mekong River Commission)-GTZ (German Technical Cooperation) WSMP please refer to:
http://www.mrcmekong.org/annual_report/2008/Mekong-livelihood-AIFP.htm
http://www.mrcmekong.org/programmes/AIFP/watershed-management-project.htm
http://www.mrcmekong.org/download/Papers/Siligato-et-al-MRC-GTZ-WSMP.pdf#search=%22GTZ%22

2) Multi-spectral image, 2.5 m resolution, manual interpretation (on-screen digitizing) of true color bands (1,2,3), scale 1:20000

3) ARC GIS 9.3

4) All data and documents are kept at the WSM Learning & Information Center, Siem Reap Provincial Hall

5) Authority for the Protection and Management of Angkor and the Region of Siem Reap

6) Provincial Dept. of Water Resources and Meteorology

7) National Institute of Statistics, Ministry of Planning, 1998

8) MRC-GTZ: personal communication April 2010

References

FAO (2006): World reference base for soil resources 2006. A framework for international classification, correlation and communication.- World Soil Resources Reports 103; Rome

FAO (2008): Community Forestry Development in Northwestern Cambodia. Project Findings and Recommendations. – FAO/Government Cooperative Programme

GARAMI, F. & KERTA, I. (1993): Water Management in the Angkor Area. Budapest: Angkor Foundation

JICA (2006): The Study on Integrated Master Plan for Sustainable Development of Siem Reap / Angkor Town in the Kingdom of Cambodia. – Siem Reap Province and APSARA Authority, the Royal Government of Cambodia, Japan International Cooperation Agency. Final Report.

JSA (1996): Annual Report on the Technical Survey of Angkor Monument 1996. Japanese Government Team For Safeguarding Angkor, UNESCO / Japanese Trust Fund for the Preservation of the World Cultural Heritage

KIRSCH, H., THAN, S., SUNTHAN, H., SOKHOM, T., & KEN, S.R. (2008): Management of Pilot Watershed Areas in Cambodia: Watershed Profile of the Stung Siem Reap Watershed 2008; Siem Reap (MRC-GTZ).

KUMMU, M (2003): The National Environment and Historical Water Management of Angkor Cambodia.

LUSTIG, T., FLETCHER, R., KUMMU, M., POTTIER, CH., & PENNY, D. (2008): Did traditional cultures live in harmony with nature? Lessons from Angkor, Cambodia. – In: KUMMU, M., KESKINEN, M., & VARIS, O. [Eds.]: Modern Myths of the Mekong: 81-94, Water & Development Publications; Helsinki (University of Technology).

MIN, B., KIRSCH, H., & DÜMMER, I. (2003): Participatory Land Use Planning in Cambodia: Concept and Experiences after the first year. – KEN, S.R., CARSON, T., RIEBE, K., COX, S. & KASCHKE, E. VAN [Eds.] (2005): The Development of Community Based Natural Resources Management (CBNRM) in Cambodia. – WWF Cambodia, CBNRM Learning Institute; Phnom Penh.

MRC (2007): Watershed Management Resource Kit. – Draft Edition 8/2007; Vientiane

SCHINDELE, W., HOU, K., KEN, S.R., UNG, L., & MAO, S. (2004): Management of Pilot Watershed Areas in Cambodia. Baseline Survey. - Part I: Framework for Land and Forest Resources Management in Cambodia, Part II: Baseline Survey Siem Reap Pilot Area; Phnom Penh (MRC-GTZ).

WORLD BANK (2003): Cambodia Environment Monitor 2003; Cambodia.

WSMP (2008): Climate Change Adaptation for Watershed Management in the Lower Mekong Basin. Working Document. - Watershed Management Project (WSMP) under the Irrigation, Agriculture and Forestry Programme (AIFP) of the Mekong River Commission (MRC); Vientiane.

YU, Y. (2008): Draft Report on local knowledge survey in Siem Reap watershed. – MRC-GTZ WSMP.

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