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Impacts of land use changes on the hydrologic behavior of small tropical headwater catchments in the Colombian Andes

Diplomarbeit unter Leitung von Prof. Dr. Markus Weiler

Freiburg im Breisgau

Januar 2010

A dream you dream alone is only a dream. A dream you dream together is reality.

- J. Lennon -

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V. Abstract

Filandia is a small municipality located in the coffee growing region of Columbia. The region is subject to persistent land use changes due to socio-economic factors. The water source for the entire municipality consists of three small headwater catchments located between 2000 m. up to 2200 m.a.s.l. The climate is characterized by a bi-modal annual precipitation cycle which causes significant low flows during June and August. Despite the annual average precipitation of near 3000mm the low flow season causes water scarcities for the entire municipality. It is possible that prospective land use transformations within the three catchments impact their hydrologic behavior and therefore increase or even attenuate the water scarcity.

The aim of this study was the development of a model that describes the impacts of different land use portions on the runoff behavior of three small tropical headwater catchments. Furthermore it is of special interest if particular alterations of land use are likely to result in decreasing low flows. Previous research which was done within these catchments suggests that the three catchments are principally comparable in terms of geology soils and climate and that the differences in their daily, monthly and annual runoff behavior are mainly a result of differing portions of land cover. Based on this assumption the primary idea consisted of the parameterization of a model that would be able to reflect the discharge behaviors of all of the three catchments and that would give an outlook to possible impacts of changing land use portions in turn. Additionally, in a next step it could estimate the possible impacts of changing climatic boundary conditions. Due to limited spatial information, such as digital elevation models, the physical lumped parameter model Brook90 was applied to single land cover compartments and then combined to the catchment discharge. In fact a Hydrologic Response Unit concept was applied without the need of any high resolution spatial data. The relative limited knowledge of physical parameters which are practicable to describe the dominant hydrologic processes led to the need of determining these variables. Since variables without explicable reference to the characteristics of the study site are likely to result in misinterpretations, the emphasis of this study was to determine these relevant variables as reasonable as possible. In a second step the application of the model was done and tested for observed discharges. Overall the lack of particular knowledge of physical parameters as well as short meteorological time series caused relatively high uncertainties in discharge estimations and the model could only partly explain the observed data. Especially during the low flow season deviations to observed streamflow was relatively high. However, the model was able to reflect the principal flow behaviors within the three catchments and on annual basis the error was small.

1 Introduction

Renewing fresh water comprises a tiny fraction of the global water pool but it is the foundation of life in terrestrial and freshwater ecosystems. For humanity, fresh water is a fundamental resource, integral to all ecological and societal activities, including food and energy supply, transportation, waste disposal, industrial development and human health. Yet water resources are unevenly distributed and some regions of the world are extremely water short. Even in water rich countries, water supply on regional basis is subject to limitations and scarcity due to socio-economic and geographical differences as well as seasonality of precipitation patterns.

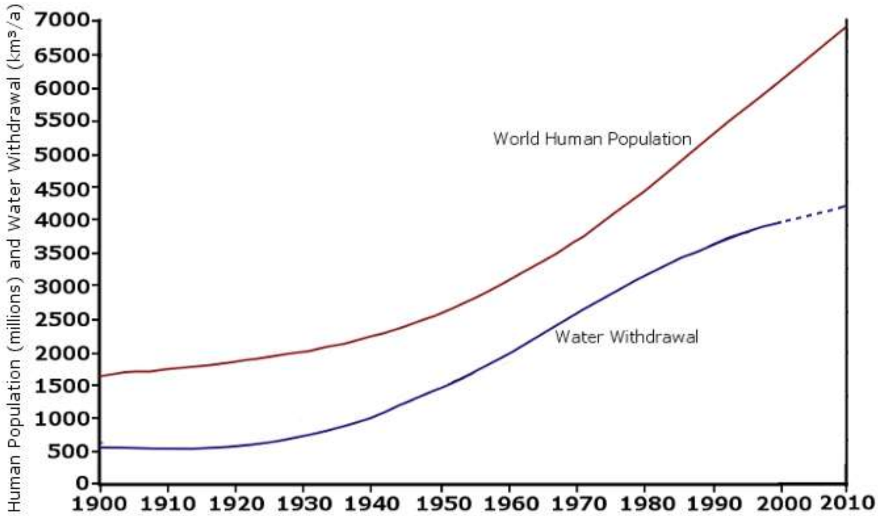

Figure 1.1: World water use and human population, redrawn and updated from Gleick, (1998). Dashed line is based on forecasts (FAO, 2010).

In the coming centuries, climate change and a growing imbalance among fresh water supply, consumption, and population will alter the water cycle dramatically. Many regions of the world are already limited by the amount and quality of available water. In the next 30 yr alone, accessible runoff is unlikely to increase more than 10% , but until 2030 the earth's population is projected to rise by approximately 20% . The highest population growing rates are expected to affect mostly these regions with already limited access to fresh water resources . Scarcities are likely to increase in these regions, which is even enhanced by the fact that most of them belong to so-called development countries with infrastructural and political problems. High population growth but also improved living standards cause raising demand of fresh-water resources. If these are limited, it can lead to serious problems such as conflicts and humanitarian emergencies – on national as well as on regional scale . Even if the raising withdrawals shows an easing of the tension, it is mostly the result of a higher efficiency in water usage by industrial countries and does not improve the situation in the problematic regions .

Water, especially fresh water, is directly linked to human health, which is in turn the most important requirement for economical development. Furthermore water is an essential resource for agriculture which includes crop cultivation just as stock farming. Again, this affects food supply and therefore human health and economy. Wetlands such as rivers and lakes, which are species-rich ecosystems and beyond that often used for water supply as well as for outdoor leisure activities, play an even more important role. Most of the points mentioned above imply an intervention in these complex and sensitive ecosystems. Agricultural practices can cause fundamental changes in infiltrability of water and water holding capacity of soils, what can in turn lead to flooding and therefore surface erosion. This again affects agricultural productivity via soil properties and so on. Another potential impact in this context is the decrease of groundwater recharge, what directly affects water availability for all of the stated dependencies and therefore not least the availability for human withdrawals.

In the past 100 yr, the amount of water globally withdrawn by humans and the land area under irrigation have risen exponentially (Figure 1.1). A global perspective on water withdrawals is important for ensuring sustainable water use, but is insufficient for regional and local stability. How fresh water is managed in particular basins and individual watersheds is the key to sustainable water management . A perfect sustainable water resource management needs to consider all related aspects such as clime, agriculture, economy, environment and social issues. Indeed, all of these aspects are interacting, and then react again to these reciprocal influences. On the one hand, taking sustainable decisions becomes even more complicated but on the other hand it gets even more essential. There are a vast number of potential wrong decisions which were partially already made and implemented. Sometimes due to a lack of better knowledge, sometimes because of short-range economical interests that did prevail. In other cases, such as long term land use changes, nobody actually was in the position to decide or rather to see neither the evolving process nor its negative impacts. However, scientific work is needed to bring the facts or as many facts as possible, to enable sustainable decisions. In the context of water, a sustainable water resource management as well as adjustments of critical decisions or developments done in history have to be ensured. Land use change or landscape transformation definitely have got impacts on the water balance of tropical ecosystems , since it directly influences soil properties, water usage by plants withdrawals by agronomy and industry to name but a few. The knowledge or a plausible assessment of these influences and the related effects is therefore an important contribution for further planning.

1.1 Landscape transformation in the Colombian Andes

Latin America is vulgo a treasure of biodiversity and Colombia is one of the most diverse regions for flora and fauna in the world. The Colombian Andean montane forest has moreover a high level of endemism and is among the least known ecosystems in the tropics . Due to the relatively high population density of the montane Andean region the pressure of its ecosystem is generally high. Since pre-Columbian times, Colombia has undergone transformations of large parts of its natural ecosystems, in particular in the Andean Region

In non-tropical regions mountains may be seen as living space of an inhospitable nature. Mountains may be barriers to human activities, areas of inhospitable climate with frequent natural hazards, such as landslides and avalanches and regions of severe cold. However, in the tropical mountains land that is hospitable to human activity is extended altitudinally due to climatic factors, and therefore the living space is vertically expanded. Historically, outside of the tropics permanent settlements were mostly restricted to lower levels of the mountains. In contrast to that, permanent settlements in the tropical Andes lay at higher altitudes and seasonal supplementary areas lay on the lower slopes and even in the hot lowlands . Estimates of the pre Spaniards Colombian population amount to at least 5 million indigenes who mostly settled (approximately 60%) in the Andean regions above 2500 m . Permanent settlements are proved to exist for more than 1500 years before the Spanish conquest . This indicates a process of ecosystem transformation, which was already induced long before the first conqueror entered the country. The transformation process went along with slash-and burn- agriculture which should have favored the existence of mosaics of natural and semi-natural vegetations associated with cultivated fields .

Due to the arrival of the Spaniards land use changed fundamentally. Cattle were introduced and the population got partially concentrated on urban areas. With regard to land use change, the early Spanish colonization had mostly two impacts. Due to the introduction of cattle, the type of agro-system and therefore also the natural ecosystem changed at least partially to pasture farming. Because of the urban concentration and the drastic reduction of the indigene population, large formerly cultivated areas of the higher Andes got exterminated and possibly rejuvenated back to natural ecosystems. At the same time the impact of grazing activities must have been strong, especially in areas with a more defined dry season where fire could be easily used for grassland management .

With a growth of population, beginning in 1800, the mentioned processes and renewed farming as well as forestry activities led to the more recently cultural landscape with less than 31% of the natural Andean forest remaining . Between 1940 and 1964 an increase in crop cultivation is registered. This may be a result of the upcoming of commercial agriculture in Colombia and became even more intensified with the general liberalization of the market Today, the remaining forest areas are at least partially fragmented which implicates further degradation of these ecosystems.

With the beginning of the 20^{th} century coffee plantations became more and more important , which resulted in the landscape, today known as the coffee growing region. Between 1920 and 1950 Colombia became a first order coffee exporter which in turn means a increase in coffee cultivation and a higher intense of agricultural usage of the related area as well as an expansion of the agriculture frontier. Since its beginning, coffee cultivation has developed accompanied by other kinds of crop cultivation and with cattle breeding. Of the 4.5 million hectare contained in Colombia's coffee growing zone in 1970, a little less than one fourth were planted with coffee. While the mean size of a coffee farm was 15.05 ha, the mean coffee-grove size of each *finca* was barely 3.52 ha . This implies the renewed induce of meadows with more or less grazing activities and cultivation of crops for aliment production.

In 1987 transformed ecosystems covered 50% of the total area of the coffee growing region and 33% corresponded to natural ecosystems . These estimates are probably vague, since it is not clear what portions are real primeval forest and what portions are *just* regenerated pre-Columbian farm land. Even if this may not play an evident role, because the regenerated forest might be a fully functional tropical forest ecosystem which reaches or almost reaches former states, it should be clear, that dealing with natural tropical forest is not absolutely in meaning of primeval natural forest. However, it is a fact that the conversion from a natural kind of forest to secondary ecosystems prevails during 1950-1980. As a consequence, the areas where coffee cultivation was done in a traditional way became reduced . Traditional coffee cultivation is a shaded cultivation. Coffee trees are planted within natural forests and are therefore shaded by a mostly natural canopy. This cultivation technique ensures a high level of remaining natural structures, a well developed litter layer as well as a relatively high biodiversity. At the same time it extends the period between two harvests and also reduces the yield per ha of planted area per harvest. Within technified coffee production systems the coffee tree density per ha is much higher and due to a shorter time-space between two harvests, up to three harvests per year are possible . Another form of coffee production which replaced the shaded cultivation is the crop associated cultivation, where coffee trees are accompanied by crops like beans, yucca and corn, which indicates a low level of biodiversity and an intense agro-cultural usage similar to the unshaded monoculture.

With the dropping of the international coffee prices in the late 1980s, a new change in land usage and therefore a new land cover transformation process started. The coffee prices dropped from above 2 US$/lb to 0.6US$/lb within one year. The outcome of this was an increase in semi-natural ecosystem cover . Coffee plantations got transformed to pastures, since livestock breeding is generally less labor intensive and besides that, meat prices were raising. This process prevails and is accompanied by a general tendency to urbanization, which again indicates migration from rural towards urban areas and the appearance of secondary ecosystems such as shrublands.

Within the coffee growing region, today at least 50% of the area corresponds to anthropic land use, evidence of the high pressure that forest ecosystems had endured in these regions .

1.2 Water scarcity in Filandia

From a hydrological point of view, land use changes such as forest cover removals generally causes important changes in runoff and sediment yield. The literature on forest hydrology reveals that the reduction in normal vegetation levels will likely increase annual water yield and may either raise or lower the dry season baseflow . Intensification of land use that involves substantial soil compaction, will certainly lead to an increase in the flood potential.

In forest areas, land use change may lead to major alterations in rates of evapotranspiration, which is compared to temperate or arid areas not evidently the main limiting factor of dry season flow .

Filandia is a municipality of Quindío Colombia and is located in the coffee growing region. It has a population of approximately 15000 people among them 44% are living in the urban area that covers less than 1% of the 10.94 km² of the municipality. Filandia's economy was based on coffee cultivation for several decades. At the end of the 1980s, the dropping coffee prices coincided with a widespread infestation of the coffee borer beetle. During this period, many farms abandoned their coffee production and replaced it with pastures for livestock breeding under intensive management systems .

The water source for the entire municipality of Filandia consists of three small catchments Figure 1.2 which are located within the farmland of three productive farms (dairy farms and meet production). As stated in Roa-García (2009), these farms exert different degrees of pressure on the related ecosystems which are mainly grasslands, forested areas and wetlands. Besides the fact that the region belongs to the humid tropics, Filandia is subject to water scarcity during periods of limited rainfall. The water supply of the households within the municipality is served by two providers: ESAQUIN is serving the urban area and RR (Rural Regional) is serving the rural area. ESAQUIN has a concession for the mining of 32 liters per second from Bolillos Creek which is the resulting stream of the confluence of two of the three catchments (Bolillos 1 and Bolillos 2). RR has a concession of 7 liters per second from Bolillos Creek, but takes also water from Barro Blanco creek without having a concession (Roa-García, 2009).

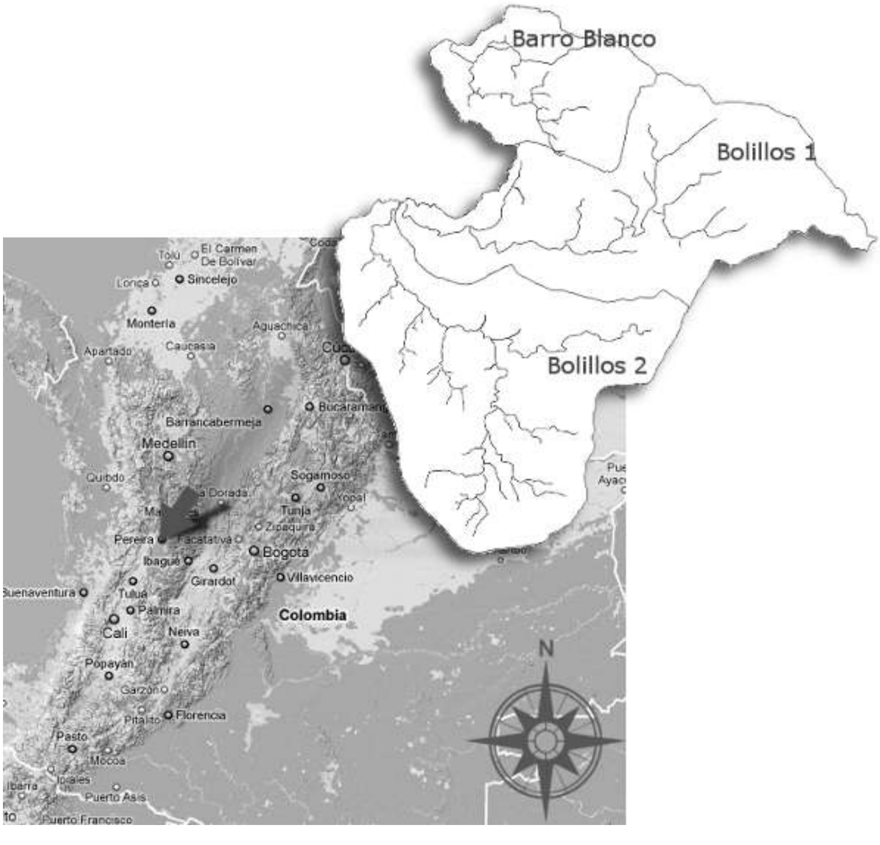

Figure 1.2: Study site and its location within Colombia

According to Roa-García (2009), there is generally a bias in water use and availability in relation to income and socio economic factors. Particularly in rural areas, where the water consumption due to agricultural activities is relatively high, the water shortage or service disruption during dryer months determines the need of alternative water sources. Hence, larger farms have own storage tanks with capacity for a few days. But not only farms are pertained; water scarcity affects also the public sector. Roa-García reported two primary schools which respond to water shortage by using water reserves from tanks but also with shortened operating if the service break down persists for periods longer than a few days. Generally one can say that the households developed individual copping mechanism to bridge the service break downs. These capable provisions such as reservoirs or pumps are however limited to households with higher incomes or the public sector.

During higher precipitation periods, water scarcity is definitely not a problem, but the occurring of peakflows can cause high sediment loads which preclude the stream water from supplying the water pipework. As stated by Roa-García, service interruptions due to sediment load usually do not last for more than single days. This high peakflows are mostly caused by the B2 catchment, which is assumed to produce high amounts of fast overland flows that contribute to such peaks. In this context another reported problem is the occurring of single torrential flow events, even during the dry season (Roa-García, 2009), which carry suspended loads that probably got deposited in banks and gullies during lower flows.

The granted concessions for the two water providers of 32 liters per second and 7 liters per second respectively, correspond to 101088 cubic meters per month. Comparing this amount of water with the outflow of the two catchments, the concessions are above the observed flows for several of the dry months (Roa-García,2009). The concessions respectively exceed the flow by approximately several 1000 m^3 in August and September 2006.

1.3 Objectives and approach

As described in the previous chapters, the Filandia municipality is subject to water supply shortfalls during several periods of the year with an emphasis on the dry periods. The main reason for these shortfalls is the minimized dry season outflow in addition to high sediment loads. The water source for the entire municipality is driven by three headwater catchments which are subject to land use of differing intensity. A previously made study applied to these catchments demonstrated several relations between the land use, the respectively surface cover type and the runoff behaviors of the catchments and suggests that these are the main controllers for the differences in catchment outflow (Roa-García, 2009). Furthermore it is assumed that common drivers like climate, soils and geology are principally comparable and do not account for substantial deviations in runoff behavior.

In the present study it is tried to account for the differences of the land cover and to conceptualize them in a hydrologic model which enables to estimate landuse impacts on flow behavior. Following Roa-García (2009), the idea is that the hydrological functions of the main cover types are principally comparable and that most of the differences are the respective portions within the several catchments. If it is possible to characterize the different catchment outflows by the definition of the hydrological characteristics of these cover types and their relative portions, it is probably possible to give an outlook about the potential effects caused by increasing or decreasing of these relative portions through changes in land management practice. As a consequence it would be possible to recommend particular measures to improve or preserve the present state and to point out that other measures or trends in land management could further intensify the existing problematic. However, the relative limited availability of data in respect to montane tropical landscapes, requires a special emphasis to the data determination.

1.4 State of the art

As described before, land use is an essential input parameter for hydrological modeling, because of its direct impacts on the quantity and quality of water. Processes which are commonly considered in this respect are transpiration, evaporation, interception and surface runoff .

Hydrological models that could be used in the assessment of land use impacts can be differentiated in two groups. The more simple models do have land use related parameters that are fixed for the entire model run. There is no feedback between the properties of the land use and the hydrology. The second group is characterized by fixed land use areas but some of the parameters react to changing environmental conditions as for example evapotranspiration. The evapotranspiration is a function of plant growth period and varies therefore over the year or even the day. Such approaches are implemented in many models originating mostly from the agricultural sector. Examples for such models are EPIC and SWAT or models like MIKE-SHE which achieve this by additional modules. Generally, some processes in these models are described by differential equations based on simplified hydraulic laws, other processes are expressed by empirical algebraic equations. More recent conceptual models have incorporated soil moisture replenishment, depletion and redistribution for dynamic variation in areas contributing to direct runoff (Arnold and Fohrer, 2005). Such models obviously have many advantages. Single processes that are influencing each other in a natural environment are also depending on each other within the model. Though, the disadvantages are obvious as well. Applying such models requires a fundamental knowledge of the particular ecosystem and a high availability of ecologic data.

Another differentiation, which is often made, consists of so called lumped and distributed conceptual models. Lumped models do generally not distinguish between single units within the modeled area and the discharge at the watershed outlet is described based on a global dynamic of the system, the distributed models account generally for different units (HRU's or Hydrologic Response Units) or for grid cells. Their study area is rasterized and the watershed response is a composite of the responses of the units or grids. The land use information for distributed models is mostly based on remote sensing images or land use maps.The different classes are extracted and used directly for raster based models (e.g. TOPMODEL , MIKE-SHE), or consolidated to hydrologic response units (e.g. SWAT, HBV). Generally, distributed hydrologic models feature the capability to incorporate a variety of spatially varying data from a proliferating set of databases on land use, land and soil characteristics, and high resolution precipitation, temperature, and other forcing input. In addition to that they are facilitating simulations and prediction with higher resolution than lumped models .

Due to the mentioned benefits (spatial resolution and the link between this spatial information and the generated results) studies using distributed models appear more and more during the last decades. Higher computing power, which is a fundamental resource for complex distributed models (for raster/grid based models even more than for HRU based models due to the parametrical generalization that is made in applying HRU's) supports this development. Another reason consists of the better availability of spatial data like digital elevation models which nowadays have a resolution for the entire globe of 1 km e.g. GTOPO30 , or for a limited part of the globe at least of 90 m e.g. SRTM . Such global digital elevation models, now enable the use of distributed models even for areas where the spatial information was fragmentary or not present at all. Today there exists a wide range of different models which have an emphasis on including land cover type related parameters. An overview is given by Todini (1988), or more recent by . A more general essay about a wide range of aspects concerning land use modeling can be found in .

However, complex models like SHE , which simulates water movement in a basin with the finite difference solution of the partial differentiation equation describing the process overland and channel flow, unsaturated and saturated subsurface flow, interception, evapotranspiration etc., have a substantial data requirement.The performance in respect to the particular goals, is not necessarily better than for simpler models with less requirements .

There exists a wide range of papers concerning land use impacts on runoff. For a relatively large scale Van Der Ploeg et al. (2002), have analyzed land use change on floods for German rivers with a special focus on the Elbe. They found that, in addition to changes in precipitation, a decrease of pastures and an increase of grain crops might be responsible for a part of observed changes in flood characteristics. An another effect may be attributed to the artificial drainage of approximately 20% of the agricultural land.

A more integrated study, by combining the agro-economic model ProLand with the distributed conceptual model SWAT, was done by Weber et. al. (2001). The scenario data derived from ProLand led to an increase in meadows or grasslands which caused a significant increase in stream runoff and overland flow. The overall study site included an area of 1100 m² which was mostly related to agricultural usage, though there was a large portion of fallow land. To adapt SWAT to the regional characteristics, all relational databases which are used by SWAT, such as weather, soil, tillage and crop data were substituted by regional data sets. A management database for typical regional cropping systems was also implemented into the model .

A further study of land use impacts on runoff was done by Fohrer et al. (2001). Like many other studies within this subject, the approach was done with the SWAT model. In a first step the model has been calibrated and validated for four mesoscale watersheds with differing land use distributions. Then the model performance for changing land use has been tested in an artificial watershed with a single crop at one time and one underlying soil type to eliminate the complex interactions of natural watersheds . In a next step land use changing scenarios for Dietzhölze watershed were developed on the basis of the agro-economic model ProLand. With the land use patterns derived from these scenarios SWAT was applied and resulted in a relatively modest effect on the annual scale, due to compensating effects of the complex watershed. The scenario based increase of grasslands resulted in amplified peakflows during higher precipitation periods .

The previously mentioned studies are just a small selection of a high number of studies applied within European watersheds. The investigation of land use impacts on hydrologic behaviors inside European areas does generally imply a high availability of land use related data, geological maps as well as climatic data with a relatively high temporal and spatial resolution and extended time series. In tropical catchments the availability of such information is generally limited , which consequently leads to a limited amount of studies in the relevant context. However, there are present papers that are dealing with land use effects in tropical watersheds. Giertz et al. (2006), used a modified version of the 1-D SVAT-model SIMULAT and applied this semi-distributed hillslope version (SIMULAT-H) to a tropical watershed in a tropical head water catchment in Benin. The benefit of a good database enabled the evaluation of the model in a multi criteria validation using discharge, discharge components and soil moisture data . Their modeled results had a relatively good performance whereupon their database due to extensive previous work within the watershed contained data concerning hydrology, hydrogeology, soil properties, soil degradation and agricultural usage for the entire 30 km^2 watershed.

Legesse et al. (2003), were applying the HRU based US Geologic Survey model PRMS successfully in a semi arid tropical watershed. The input parameters were estimated from existing data or calibrated against measured discharge, which were available for the past 11 years. They pointed out that conversions of present pastures to woodland to an amount of 15% would cause a decrease of the discharge up to 8% .

For Latin American tropical watersheds, several present papers are dealing with forest pasture conversion and its impacts on the runoff generation. Most of these approaches are indeed related to

Amazonian areas . A recent study in this context was done by Germer et al. (2009), within small watersheds in Brazilian Amazon. The paired catchment study compared a small forest with an adjacent cleared watershed. The latter was logged 20 years before and since that extensively used for cattle grazing. The comparison was done by matching the runoff response of the two first order streams to single events as well as identifying different preferential flowpats via solute transport measurements. The results showed a significant increase of stormpeaks for the cleared areas, where an increasing quick overland flow component was the important forcing factor .

In regard to tropical mountainous regions, Braud et al. (1999), performed a study in the Argentinean Andes. The particular interest was to understand the mechanism leading to runoff generation and moreover the generation of flash floods in the study area . The distributed (grid-based) model ANSWERS respectively its continuous version was used for this approach. The model generally was able to reproduce the fast increase of the observed event responses but underestimated large peaks. However, the overall performance was quite satisfactory, since the model could reproduce the storm runoffs in general, which was indeed the main goal of this study . Certainly, the input database in this approach was broad and contained a 30 m resolution map of geology and a digital elevation model of the same resolution, which consisted of approximately 6000 grid cells for the entire catchment.

Most of the previously mentioned studies are based on distributed continuous rainfall-runoff models which have mostly a high demand to spatial data. In a Philippine watershed Combalicer et al. (2010) recently applied the lumped parameter model Brook90 and derived acceptable results. The model was not calibrated by a generic optimization; at the most a manually fine tuning was done for selected parameters . Combalicer et al. (2010) documented the principal possibility to obtain acceptable results with a lumped physical model within a small tropical forested watershed (377 ha), albeit this watershed was well documented in terms of hydrology, soils and vegetation due to previous work. This is not self-evident since Brook90 originally was developed and tested under tempered climatic conditions and compared to this the climatic conditions in the study site were fairly extreme. The high annual precipitation period (up to 2300 mm a^{-1}) has a short break during the dry period in which admittedly the model produced the highest deviations from measured runoffs.

Karvonen et al. (1999), stated the general difficulty to obtain all the necessary information to use a fully distributed physical model like SHE. The generation of an adequate database is costly to assemble and may be unavailable for large catchments . They stated further, that the use of the other extreme, a lumped model which considers the whole catchment (catchment, sub-catchment, aquifer, etc.) as a single unit, is not able to handle different land use types and the areal diversity of the hydrological process. Taking this into account, they created particular characteristic profiles for each of the defined land cover unit within the study site. The runoff amount from a land use unit was then calculated by relating the area of the particular land use portion to the characteristic profile. Each of this characteristic profiles stands for an individual calculation scheme of the particular runoff in dependence of the respective dominant runoff process (saturation surface flow, Darcyan flow, unsaturated flow through the soil according to Richards law etc.). The influence of the shape of the hydrograph was realized by applying the geomorphologic instantaneous unit hydrograph (GIHU) concept. Snowmelt was calculated by use of an additional characteristic profile . Their concept was subsequently applied within a mesoscale watershed of 1290 km² for which 25 characteristic profiles, based on LANDSAT images and land use data from the Finnish Environment Institute, were defined. A calibration dataset of 2 years was used to calibrate the channel routing part of the model concept . The coefficient of determination for modeled periods varied between 0.638 and 0.782. It can be said, that the main concept of this approach is the definition of hydrological response units (characteristic profiles), wherefore their approach is generally an application of a semi distributed concept. The main conceptual difference to *usual* distributed or semi distributed models is the decoupling of the response units and the separated calculations of the particular response of these units, which in fact consists of the combination of a number of individual lumped models.

In summary it can be said, that there are generally more recent studies in the context of land use runoff interactions that are done with semi distributed or even distributed models. Most of these studies are characterized by a relatively high data availability concerning the input parameters or at least an extended precipitation-runoff time series which could be used for the model calibration. The emphasis of these studies is indeed focused on forest to pasture conversions.A number of studies was done in Western Europe and for scales of more than 100 km². However, the concept of is only of particular interest for the present study, because of the lack of topographic data with an appropriate resolution. These matters of fact are preventing the use of an *established* fully distributed model and the concept of Karvonen et. Al. (1999),which is in fact the combination of single lumped models obtain reasonable results. Also of particular interest is the study of Combalicer et al. (2010), since they showed the general feasability of applying the lumped model Brook90 to a smal tropical forested watershed. The physical basis of a model like Brook90 could help to estimate unknown parameters within a known physical range.

2 Study Area

The study area involves three small catchments in the coffee growing region of Columbia, on the western side of the central cordillera of the Andes (Figure 1.2). The catchments are located in 4.67° N, 75.63° W and border each other (Roa-García, 2009). The study site belongs to Filandia which is a municipality of the Quindío department. The area belongs to the coffee growing region, a mountainous area with a high population density in comparison to the Columbian mean.

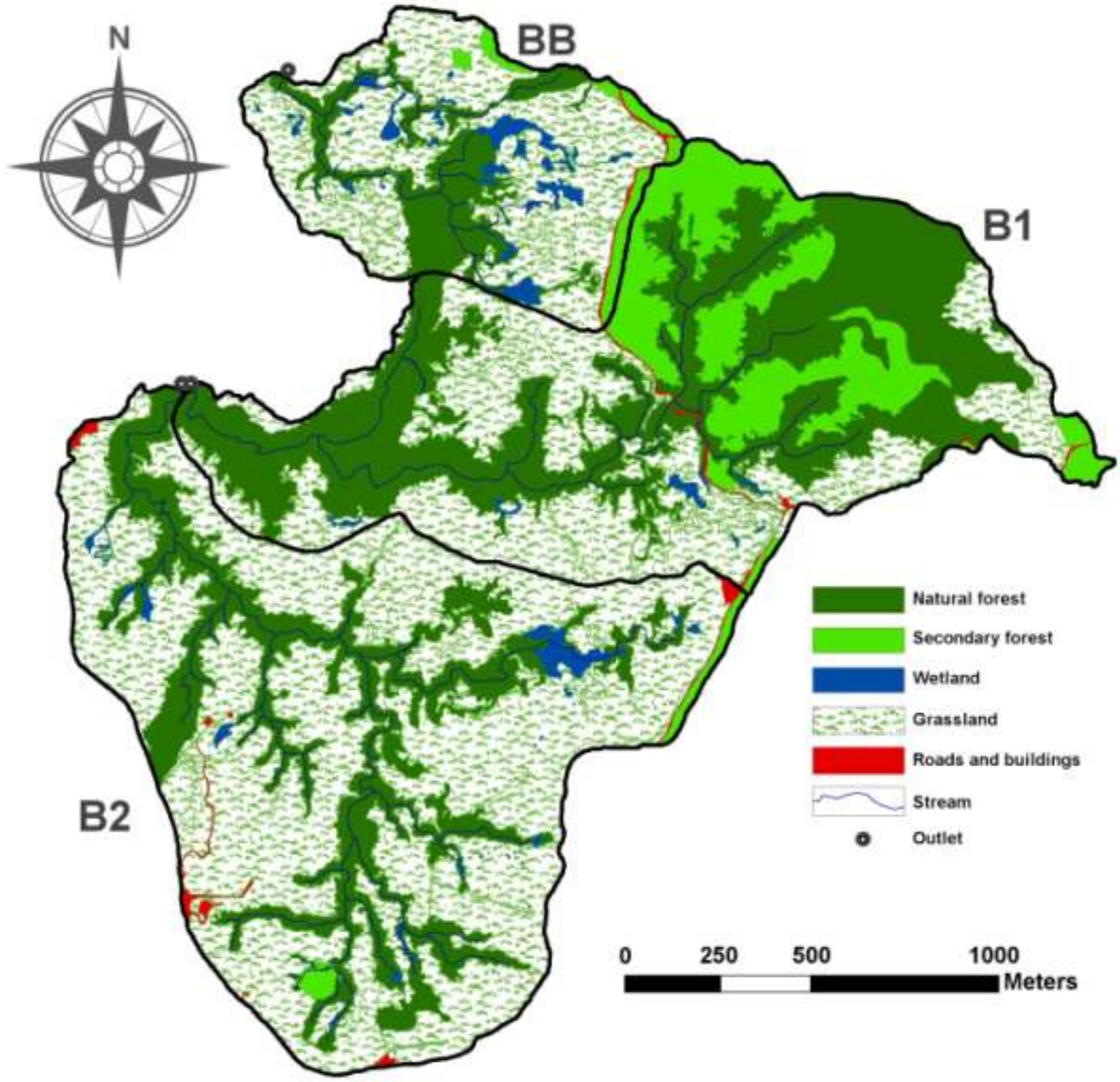

Figure 2.1: Study site with main land cover types

The whole Study site encompasses an area of 4 km² and stretches from 2000 m. up to 2200 m.a.s.l. As mentioned before, the study site contains three small headwater catchments (Barro Blanco, Bolillos 1, and Bolillos 2), all of them differ respectively in size, land use intensity and portions of land cover types (Figure 2.1). Barro Blanco has an area of 0.691 km² and is the smallest one of the three catchments. Bolillos 1 and Bolillos 2 have an area of 1.586 km² and 1.791 km². To simplify the terminology and to follow the existing literature (cf. Roa-García 2009), in the following the catchments are called BB (Barro Blanco), B1 (Bollilos 1) and B2 (Bollilos 2). The catchments drain into the Cauca River (Roa-García, 2009), which is part of the Rio Magdalena drainage system and flows north-west to the carribian sea .

Besides that the catchments are relatively small they represent the main water source for the entire Filandia municipality as well as for the economic activities of the approximately 15000 residents of the area . Since the Filandia Municipality belongs to the Quindío department, with a relative high population density, the nature of the local ecosystems was transformed comprehensively towards more intensiv land use and less aboriginal conditions . Due to a general rural-urban migration in development countries, the growing of the population density in rural areas such as filandia stagnates, but that does not automaticaly implies a stagnation in land transformation processes. Recent transformations are related to a lower rural density but a higher percentage of pastures . In the whole Quindío area, only 3,21% or 52134 ha of the landscape is still classified as natural ecosystems but the percentage of so called semi-natural ecosystems, which includes pastures, increased since 1987 . In order to this, most of the land in the sites is dedicaded to extensive cattle rearing, although differences of the land use intensity can be seen among the three catchments (Roa-García, 2009).

2.1 Climate

Climate in the study site is humid. The average annual precipitation recorded since 1972 has been approximately 2990 mm, whereas the sum in 1996 for B1 was 3473 mm, for B2 3073 mm and for BB 3000 mm. Average temperature was about 17.03 °C in 1996 (16.73 °C for the period 1995-1996). In the study area prevails a bi-modal annual precipitation cycle, where rainfall peaks during April-May and October-November, and is low during December-February and June-August which is mainly a consequence of the double passage of the Intertropical Convergence Zone (ITCZ). Given by Roa-García, Poveda et al. (2006), stated that the seasonal strengthening of the Chocó Jet (September-November) and weakening (February-March), partially explains why the October-November rainy season is more intense than that of April-May. Daily precipitation occurs with a unimodal diurnal peak in the afternoon, explained as convective precipitation associated with solar thermal forcing favored by the entrance of low moisture-laden winds onshore from the Caribbean and Pacific which ascend due to orographic lifting (Roa-García, 2009).

2.2 Geology and Soils

The three catchments are located in the Quindío-Risaralda Fan which was filled during the Quaternary by a sequence of stacked volcaniclastic mass flows. According to their stratigraphic succession, lateral continuity, genesis and sedimentological parameters, several individual units can be distinguished within these deposits. A sum of observations link the active fault systems, the present-day drainage patterns and the distribution of the volcaniclastic units. The basin and the volcaniclastic fans bear the imprint of three dominant major fault trends. The interaction of this transpressional multiple active system led to the formation of localized pull-apart basins that became depositional lows for the volcaniclastic units . The unit where the study site is located corresponds to one of the oldest units of the fan, exhibiting a dominantly east-west trending flow direction with a hummocky topography . According to Roa-García (2009), this has been conducive for the formation of wetlands. The Sediments are mostly clays of uniform size and arranged with pockets of crystalline coarse fragments. The unit has a volcanic ash layer of variable thickness which can reach up to ten meters at some locations. This ash layer is characterized by very low hydraulic conductivity, which limits water percolation and contributes to the formation of wetlands (Roa-García, 2009).

Soils formed from these sediments are classified as Andisols (Acrudoxic Hapludans) and characterized by high organic matter content as well as high content of allophones and imogolite. The soil forming process was dominated by rapid weathering of volcanic ash and resulted in amorphous poorly crystallized silicate minerals . Due to their high content of allophanes, imogolite and organic matter, these soils have a light bulk density (between 0.6 and 0.8 g cm^{-3} for typical Andisols), a high water holding capacity and are relatively resistant to erosion (Legowo 1987, Roa-García, 2009, Santos 2007, Rodríguez, et al. 2002).

The overall information about the general soil characteristics of the study site is relatively low. The thickness is assumed to be 1.5 m at average (Weiler, M., personal communication) and it is underlayed by the mentioned more or less impervious ash layer. A more detailed discussion can be retrieved in chapter 3.1.1.4.

2.3 Land use and landscape units

The three catchments are relatively similar in terms of climate and soil properties but do have significant differences in terms of land cover. As shown in Figure 2.1, in all of the three catchments numerous wetlands exist, although grassland and forest are the main land cover types even though the portions differ.

2.3.1 Wetlands

In the present literature there are different definitions of wetlands (e.g. as defined in the UNESCO founded Ramsar Convention , in Van der Walk "The biology of freshwater wetlands" (2006) or in Mitsch and Gosselink "Wetlands" (2007) as well as in differing definitions by several regional organizations such as the US Environmental Protection Agency), therefore it must be made clear what is meant in this thesis when dealing with wetlands. To follow previous studies in the regarding catchments, according to Keddy (2000, cited in Roa-García, 2009, p. 30) a wetland is defined as an ecosystem that arises when inundation by water produces soils dominated by anaerobic processes and forces the biota, particularly rooted plants, to exhibit adaptations to tolerate flooding. Wetlands exists in places that as a result of geomorphologic characteristics and water regime allow the accumulation of standing water that, in combination with soils, create unique conditions in the landscape (Roa-García, 2009).

Following the previous definition, BB has the highest proportion of wetlands with an area of 0.38 ha which equals 6.13% of the total catchment area. The proportion of wetlands in the other two catchments is smaller and between 0.5% and 1% respectively .

Table 2.1: Wetlands in the study site and total area of the catchments

Catchment	Number of Wetlands	Area of Wetlands (km^2)	Catchment Area ($km^{2)}$
B1	8	0.01	1.59
B2	22	0.03	1.79
BB	52	0.07	0.62

2.3.2 Forest areas

The forest areas within the three catchments differ in size (Table 2.2). B1 has the largest portion of forest (Figure 2.1), which consists of natural and secondary or plantation forest. The forested areas for BB and B2 are comparable whereas B2 has a larger total amount. Besides that, the classification as a natural forest does not necessarily mean that it is pure aboriginal forest. According to the remarks in chapter 1.1 it is likely that the area was subject to several land cover transformations in previous centuries. Therefore, natural forest is forest which was not affected by forestry or agriculture for several decades. Additionally the plant population is natural which means plants were not cultivated. However it is not clear whether natural forest is in fact secondary natural forest or if it is a relic of true natural forest, possibly encroached to fallow areas during the last centuries. Nevertheless, dealing with these areas as natural forest is in agreement with the classification of Roa-García and Reiners et al. (1994), who observed a rapid return to the species composition of primary forest. The return to original physical structure will take much more time (Reiners, et al., 1994), whereas Zimmermann et al. (2009) reports a significant reconstitution during a 10 year period which in turn suggests a total or at least almost total reconstitution during longer periods.

In contrast, the secondary forest within the study area belongs at least partially to cultivated species like eucalyptus and others. It is neither clear which portions are captured by the several species in particular, nor which composition of species is present. For a layman, the canopy structure of these secondary or plantation forests does not show a significant difference compared to the natural forest (Weiler, M., personal communication).This and the fact that the available data (e.g. soil data) were limited and did not differ between several types, secondary forest was summarized to one land cover type.

Table 2.2: Forest and grassland areas per catchment (Roa-García, 2009)

Catchment	B1		B2		BB	
	area	relative	area	relative	area	relative
Natural forest	0.812 km²	51%	0.489 km²	27%	0.156 km²	25%
Secondary forest	0.277 km²	17%	0.019 km²	1%	0.033 km²	5%
Grassland	0.477 km²	30%	1.236 km²	69%	0.387 km²	62%

2.3.3 Grassland areas

The remaining areas are dedicated to grasslands, which is used for cattle grazing. There are several parts of these pastures which have growing secondary vegetations such as shrubs. The Quick Bird image (with a resolution of 0.6 m) does not indicate a high density of this early stage secondary vegetation. According to Reiners et al. (1994) the differences between pastures converting to shrublands and pure pastures seems to be negligible in the context of soil properties. In matters of transpiration, the low density as well as the relatively small area indicates no significant influences. Therefore the grassland portions are summarized as shown in Table 2.2

3 Material and Methods

3.1 Model and parameterization

As mentioned before modeling land use impacts of three comparable catchments and comparing the modeled results with consideration of impacts due to differing land cover portions is mostly done with fully distributed models like MIKE-SHE or SWAT which makes it possible to account for the physical characteristic of different cover types. In the present approach this was not possible, since the availability of spatial data is limited. As described in chapter 1.4 Karvonen et al. (1999) were drawing characteristic profiles of different hydrologic response units and combined the calculated results of these in fact lumped single models successfully to the resulting overall catchment runoff. For the study area too less is known in terms of hydrologic behaviors to use such a concept. Using a lumped physical model would enables to describe the hydrologic behaviors with physical parameters, what in turn allows estimating poorly known values within a physical range. Combalicer et al. (2010), showed the suitability of BROOK90 to grasp the characteristics of a small tropical watershed. Putting this together led to the idea of applying the lumped physical model BROOK90 to the different areas within the catchments individually and combining the results to the total catchment. Therefore BROOK90 in this approach was used as a quasi distributed model within the HRU concept by avoiding the need of spatial data.

BROOK90 is a deterministic, process-oriented, lumped parameter hydrologic model that can be used to simulate most land surfaces at a daily time step year-round. The model has a strong physically-based description. It does not support any spatial distribution of parameters in the horizontal but concentrates on evaporation, and vertical water flow. Below ground, the model includes one to many soil layers which may have differing physical properties. Since the exact soil conditions in the study site are not known, in this study only three different soil layers will be defined. This approach seems to match the local conditions sufficiently, but detailed information about the assumptions which are made for that issue will be discussed later on. Vertical flow through these layers is obtained iteratively. The model estimates interception and transpiration from a single-layer plant canopy, soil and snow evaporation, snow accumulation and melt, soil water movement through multiple soil layers, storm flow by source area or pipe flow mechanisms, and delayed flow from soil drainage and a linear groundwater storage. Since snow related processes are not existing in the study area, all related parameters are set to zero or/and the respective subroutines are turned off.

Input variables for BROOK90 are precipitation at daily or shorter intervals, daily maximum and minimum temperatures, daily solar radiation, daily vapor pressure, and daily wind speed

Brook 90 requires a range of input parameters which does not necessarily need to be modified but enables the modeler to adjust the model in regard of for example different soil (macropore depth, hydraulic conductivity etc.) or vegetation properties (canopy height, LAI, seasonal growth etc.). All parameters are provided externally and are generally physically meaningful .

Mathematically the BROOK90 model water distribution is expressed as follows:

$$P = EVAP + FLOW + SEEP \qquad (3.1)$$

where P is the precipitation (mm), EVAP is the evaporation (mm), FLOW is the corresponding simulated total streamflow (mm) derived from surface flow, flow through the soil matrix and if considered groundwater flow, and SEEP is the deep seepage loss from groundwater (mm).

In Brook 90 potential evaporation is calculated by use of the Shuttelworth and Wallace modification of the Pennman Monteith equation. Evaporation of intercepted rain is calculated with a canopy resistance of zero and aerodynamic resistances based on canopy height, coupled with a canopy capacity and an average storm duration. For potential transpiration, canopy resistance depends on maximum leaf conductance, reduced for humidity, temperature, and light penetration. Aerodynamic resistances depend on leaf area index (LAI), and on canopy height, which determines stem area index (SAI) .In this study LAI and stem area index (SAI) does not vary with the season because the tropical montane rainforest are not subjected to considerable seasonal variations in the relevant context .

Soil evaporation resistance depends on soil water potential in the top soil layer. Actual transpiration is the lesser of potential transpiration and a soil water supply rate determined by the resistance to liquid water flow in the plants and on root distribution and soil water potential in the soil layers .

Net throughfall in Brook 90 can infiltrate into the soil matrix of the surface horizon (first possibility) infiltrate directly to deeper horizons via vertical macropore flow (second possibility), go immediately to streamflow via vertical macropore flow followed by downslope pipe flow (third possibility), or go immediately to streamflow via impaction on a variable saturated source area (fourth possibility) .

Water in the soil matrix moves vertically, according to Darcy's Law for unsaturated or saturated flow . The subroutine to model downslope flow was not used in this study, since the mean slope of the several catchments was the only available slope parameter and therefore no recognitional gain was expected. Besides that Federer (2002), does recommend not using this routine since its algorithm is crude.

Transpiration in Brook 90 is removed from each soil layer according to root density and soil-water potential. Infiltrating water can be moved directly from the surface to lower layers to simulate macropore-assisted vertical infiltration. Integration of the continuity equation is by explicit forward difference, but with a variable iteration time step that limits changes in layer water content and in potential gradients. For different layer thicknesses, the interlayer conductivity and gradient behaves as if both layers have the thickness of the thinner layer. The relationships among matric potential, soil water content, and hydraulic conductivity are parameterized by a modified Clapp and Hornberger formulation with values usually given at a hydraulic conductivity of 2 mm d^{-1}. Water is added to groundwater by gravity drainage from the deepest soil layer. The groundwater component of streamflow is simulated as a fixed fraction of groundwater each day. A fixed fraction of the groundwater outflow may be deep seepage . For detailed information about the model concept ant its realization I recommend the existing descriptions by C. Federer (e.g. Federer, et al., 2003) as well as the Brook 90 website which contains a list of related publictaions .

Since Brook 90 is a lumped parameter model, it’s not originally designed to model the impacts of land use changes on hydrogical catchments. Even though in this study Brook 90 in a first step is used to estimate daily runoff and annually water yield and its contribution from three different types of main land use or landscape units and in a second step to estimate potential land cover changes. In order to do so the catchments total areas were subdivided and Brook 90 has been applied for each partition individually with an adjusted set of parameters. The portions of the differing land use types for each of the three catchments are shown in Table 3.1 (since roads and buildings seems to be negligible and they accounts for not more than 1% of the total catchment area they were not included).

Table 3.1: Fractions of land use types (Roa-García, 2009)

Catchment	B1		B2		BB	
	Km^2	%	Km^2	%	Km^2	%
Forrest	1.1	69.1	0.51	28.3	0.19	30.6
Grasslands	0.48	30.2	1.24	69	0.39	62.9
Wetlands	0.01	0.63	0.03	1.7	0.04	6.45
Total Area	1.59	100	1.8	100	0.62	100

Afterwards daily values of the model runs for each land cover type and catchment were summarized to daily total catchment values.

3.1.1 Model Parameter

The BROOK90 is a parameter rich model and lumped by six parameters, namely, location, flow, canopy, soil as well as fixed and initial parameters. The model is site specific and has given values for its initialisation run. The main concentration of the calibration and parameter fittings focused on the canopy, soil, location and flow parameter variables that conform to the appropriate local conditions of a watershed .

3.1.1.1 Location Parameter

The location parameter file consists of site specific values like the geographic location, the mean slope and the aspect as well as average amounts of daily hours of precipitation per month. These values are different for each catchment and except the average precipitation hours, which were extracted from GIS. The location parameters for each catchment are shown in Table 3.2.

Table 3.2: Location Parameter

Catchment	**B1**	**B2**	**BB**
Latitude (° N)	4.67	4.67	4.67
Altitude min (m.a.s.l.)	1999	1999	2035
Altitude max (m.a.s.l.)	2211	2130	2148
Slope (deg)	5.71	4	7.41
Aspect (deg)	269	327.5	290.5

Average daily precipitation hours were calculated for each catchment separately and range between 2 and 7 hours (mean 4.67 hours for the year 2006).

3.1.1.2 Flow parameter

The hydrology of Andean montane rain forests as well as their conversions is not well studied. Today's research results hardly make it possible to derive generic knowledge that can be applied in a rigorous way to ungauged catchments . Due to the fact that andisols occur on mostly all latitudes under all climate conditions, the slight extensive worldwide occurrence of andisols (less than 0.8% of the earth surface) implies a smaller portion of andisols in tropical headwater systems . Due to this fact, only a few studies exist which refer to andisols in general and to andisols in the Columbian Andeans in particular especially in the context of hydrologic modeling. For the study site no exact data of some required soil related properties (e.g. thickness, number of horizons, root density, mean root length etc.) were available and due to the facts mentioned above some estimations and assumptions were made. For some values it was drawn on existing literature and related as effectively as possible to the study site. Zimmerman (2009) showed that the evolution of the saturated hydraulic conductivity and the occurrence of surface runoff due to exceeded infiltration capacity are similar between converted sites of lowland rainforest and montane rainforest in Brasil and Ecuador, respectively. Due to these results, the use of values derived from studies in the Amazonian lowland rainforest seems to be feasible, albeit the presence of direct related parameters would be desirable.

Flow parameters affect drainage and infiltration. To consider the different properties of the three land cover units three flow parameter sets were created.

3.1.1.2.1 Grassland flow parameters

The macro pore influence on infiltration and drainage is assumed to be negligible since the grassland areas were subjected to soil compaction through extensive cattle grazing (Roa-García, 2009). Additionally some potential erosion occurring after the land conversion may have had a negative effect on macro pores in the top soil. Therefore a classic top down infiltration for the grassland areas was simulated by turning the INFEXP-parameter to 0.01 (INFEXP is a dimensionless exponent that determines the distribution of infiltrated water with depth). The soils in the study site have relatively high water content. For the grassland areas the average volumetric water content ranges between 65% (B1) (63% (BB), 60% (B2)) in the wet season and 58% (B1) (56% (BB), 49% (B2)) in the dry season. In consequence of that and in combination with the soil compaction the soils are expected to produce surface flow during larger storm events. Due to the fact that the soils have a general large water holding capacity, associated with a small release coefficient (between 1.3 and 1.5 in the catchment area. 2.1-8 for typical clays and sands respectively (Roa-García, 2009), soil compaction decreases the effective storage capacity of the soils which leads to a susceptibility of saturation excess flow. The hydraulic conductivity of 15 surface grassland sites where measured by Roa-García (2009) and range between 40 and 400 mm h^{-1}. Such values are typical for semi pervious materials and contribute to hortonian overland flow during storm events. In agreement with that, Roa-García (2009) estimated that roughly 10% of the precipitation does not inflitrate into the soil on the grassland sites but becomes overland runoff.

To simulate overland flow during storm events, Brook90 was forced to calculate the soil wetness of the first 300 mm of the topsoil regarding to overland flow generation by setting the QDEPHT-Paramter to 300. This was done due to a lack of knowledge of the distribution of Ks with depht, but it is in agreement with studies from the Amazonian Basin in Brasil and a south Ecuadorian montane Rainforest site. There the probability of perched water tables between the first 12.5 cm and 20 cm of the topsoils on pasture sites was already high for the median 30 minutes rainfall intensities (0.8 mm/h), whereas the probability for the forest sites was 0. For the 95 percentile of the annual rainfall intensities (7.4mm/h) which contributed to nearly half of the annual total precipitation, the probaility for the pasture sites reached 80%, whereas that for the forest sites reached values was slightly exeeding 60% on some parts of the site but mostly didn't exeed 20% (Zimmermann und Elsenbeer, 2009). To remove a variable portion of water between field capacity and saturation, the QFPAR-Value was set to 0.3. The QFPAR-Parameter controls the fraction of water between field capacity and saturation becoming overland flow. Increasing QFPAR increases quick flow from soil dryer than field capacity and decreases it from soil wetter than field capacity. The QFFC-paramter was set to 0.2. QFFC controlling the fraction of surface runoff that is generated at field capacity. Decreasing QFFC decreases source area flow proportionally at all soil water contents within QDEPHT . To remove a fixed fraction of rainfall that reaches impermeable surfaces such as roads and open water, the IMPERV-parameter was set to 1%.

Table 3.3: Flow parameter as used in this study

Flow parameter	Grassland	Forest	Wetland
IDEPHT (mm)	-	910	0
INFEXP	0.01	0.3	0
IMPERV	0.01	0.01	0.01
BYPAR	0	1	0
QDEPHT (mm)	300	0	1500
QFPAR	0.3	0.3	0
QFFC	0.2	0.2	0.2
GSC	-	0.04	-

Parameter without reference were not used or turned off if necessary.

3.1.1.2.2 Forrest flow parameters

Other than on the grassland sites, the macro pore influence on runoff generation in tropical montane forests should be taken into account. As described in literature in humid tropical climates the gain of water caused by a higher infiltrability of forest soils can equal or exceed the loss of precipitation resulting from plant transpiration (Bruijnzeel, 2004; Bruijnzeel, 1990). Forest soils are a way more influenced by macropore building processes owing to rooting and animal burrowing (Bruijnzeel, 1990 and Critchley, et al., 1996). According to Reiners et al. (1994) conversion of tropical forest to pasture increases the bulk density significantly, accompanied with an decrease of the porosity in at least the first 15 cm of the pasture soils. The studied soils are strongly related to andisols (Reiners, et al., 1994) and therefore some of the results may be partially applicable to the current problematic.

Rooting dephts of various vegetation forms in different climatic zones are differing significantly. Ranges are between 29 cm for Tundra and 171 cm for mediteran shrublands . Considering the results from Reiners et. al (1994) plant roots are an important factor in terms of total soil porosity. The forest sites generally have a higher root density as the pastures ones and therefore a higher amount of macropores.Tropical forests have the highest root biomass (5 kg/m^2) compared to other terestrial biomes and for that reason root distributions can be used at least as a reference for the macropore distribution. This is in agreement with other studies where it is stated that forest sites have a higher permeability and due to this a better infiltrability . Macropore assisted infiltration puts a larger portion of input water (precipitation) straight into deeper soil layers which means that the classical top down infiltration through the soil matrix is displaced by a quick component through the macropore network.

In Brook90 the IDEPHT paramter combined with INFEX determines the realisation of macropore assisted infiltration. IDEPHT corresponds to the depht of vertical macropores while INFEX is an dimensionsless paramter which determines the distribution of infiltrated water with depth. To rise the portion of macropore assisted infiltration a value >0 must be chosen. Since the soil profiles of the study area are not exactly known, it is assumed that the maximum macropore depth corresponds to the maximum rooting depth of the dominant vegetation form. Typical rooting depths of several vegetation forms are described in Schenk et al. (2002) and for this study a value of 91 cm for tropical evergreen forest was used (Schenk und Jackson, 2002).Since INFEX is dimensionsless it is a more or less adjusted by instinct and therefore somewhat like an adjustment parameter. INFEX was set to 0.3 because it gained the best fit between dispersion of the runoff curve and the peakflow.

Other than on pasture sites the amount of surface runoff generation is expected to be neglible. Only during realy large events surface runoff could partialy be generated . The better permeability of the soil combined with a well developed litter layer increases the infiltrability as well as the water holding capacity in the forest sites (Critchley, et al., 1996; Bruijnzeel, 2004). A fast runoff fraction which may occur in the forest areas must therefore be routed through the soil and in Brook 90 implemented as bypass flow. The fraction of bypass flow which is generated in each soil layer depends on the same parameters as described for the grassland flow. Because bypass flow may already occur below field capacity QFPAR was set to 0.25. The fraction of water which becomes quick flow is determined with QFFC (quick flow fraction at field capacity) which was set to 0.05 for the forest sites. Both of this parameter are not physical as such and were adjusted manually for the best fit.

The forest areas are at least partly situated in the riparian zone. Whereas the grassland sites are expected not contributing significantly to base flow due to the relatively low permeability and the high water holding capacity , the forest sites are assumed to do so. The general water storage in the riparian zone in addition with the higher infiltrability of the forest soils leads to the assumption that the groundwater contribution is probably not negligible. Higher amounts of measured dry season flow of the forested B1 watershed compared to the grassland dominated B2 catchment as well as the fact that peak flows of test runs seemed consequently too high and low flows too low, are supporting this hypothesis.

Brook 90 provides a first order groundwater storage routine which is mainly controlled by the GSC parameter. To estimate GSC a runoff duration curve of measured B1 runoff was plotted. Baseflow was defined as the runoff which is exceeded in 90% of the time (NQ90). Assuming that baseflow mainly depends on the forested areas of the catchment, GSC was adjusted till a duration curve of modeled B1 forest flow was in an acceptable range of the NQ90 for the measured data. GSC therefore was 0.04. An overview of all forest flow parameters used in this approach are shown in Table 3.3.

3.1.1.2.3 Wetland Flow Parameters

Since the total wetland area of all catchments does only account for less than 2% of the total catchment area the wetlands likely have an influence on the runoff generation. As shown in Figure **3.1** BB and B1 reveal a higher frequency of longer response than B2. B1 has the biggest forest area it may have a delaying influence on the response time. BB and B2 have almost the same proportions in terms of land use except of the percentage of wetlands. Therefore it is presumable that the wetlands act as long term water storage . Another effect which is apparent in Figure **3.1** is that the first event response of BB is higher than in the other catchments indicating a higher amount of pre-event water, which in turn could illustrating the behavior as an overflow storage of the wetlands. In the longer time scale the right side of Figure **3.1** shows that the total water yield of BB is the smallest. Due to the longest mean transit time it is likely that more water becomes evaporated . All in all it should be noted that the wetlands, although relatively small in area, have an obvious influence on the runoff generation.

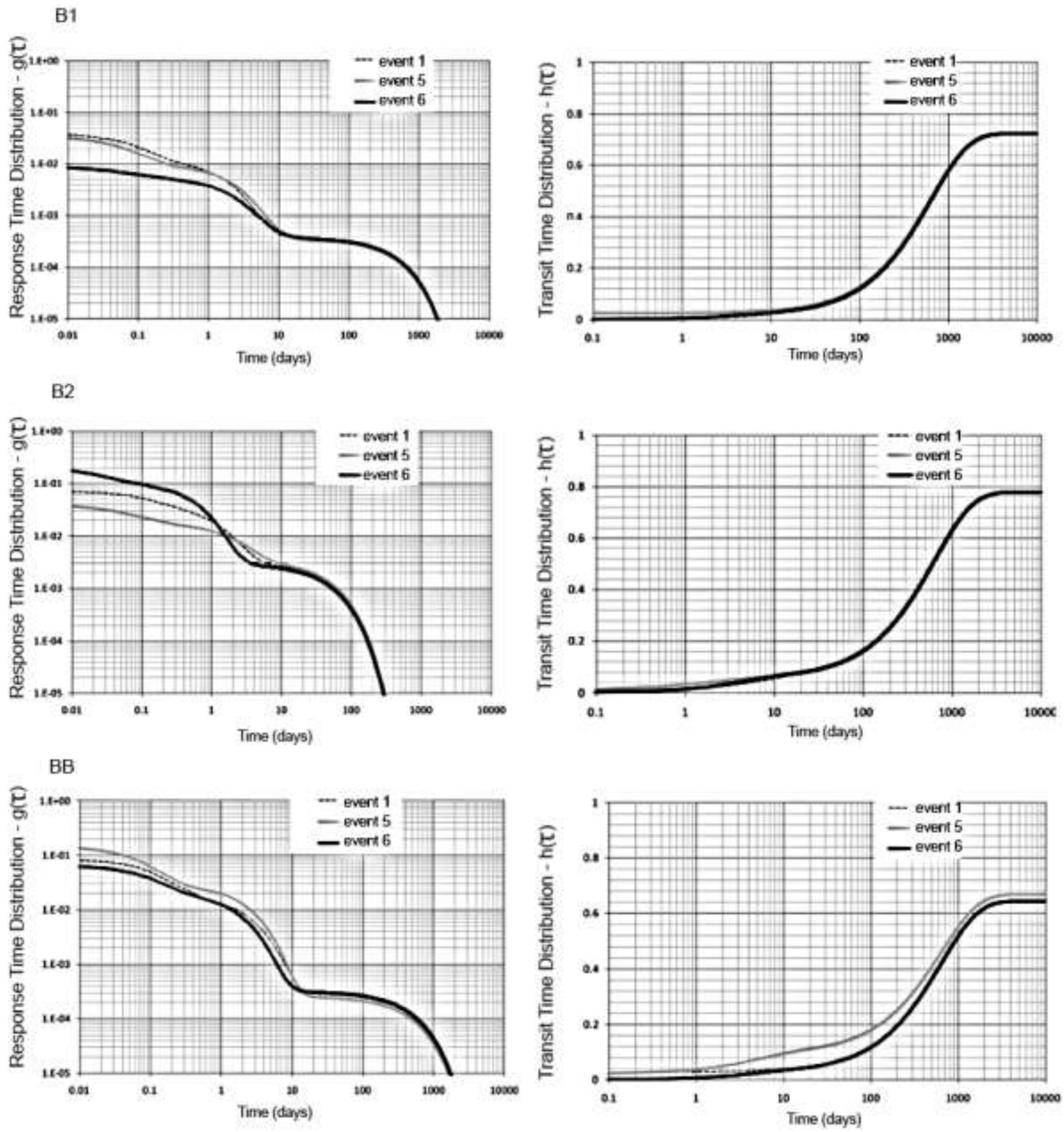

Figure 3.1: Probability density function of Response Time Distribution and cumulative probability density function of Transit Time Distribution for three different events (Roa-García, et al., 2010).

The flow parameters for the wetland areas are set with the assumptionacting like a sponge with the ability to grow and shrink depending on the actual water content (Bucher, E.H., et al., cited in Bullock, et al., 2003) but for large events also as an overflow storage with the ability to increase storm responses. In respect of that macropores or soil channels will not have an authoritative influence on the infiltration process because the soil body is already saturated or almost saturated. Additional water is stored by increasing the soil body and therefore the water table. Routing water downwards is expected to have a minor influence. The larger amount of pre-event water in the runoff response of BB catchment is probably an effect of hydraulic pressure transfer whereas some pipeflow may occur or support the pressure transfer. In regard of the previous assumptions INFEX and IDEPHT were set to 0. Due to that the soils in the wetland areas are saturated over or almost over the whole depth. QDEPHT equals the average soil thickness of 1.5 m. Notice; QDEPHT determines the number of soil layers over which wetness is calculated to determine source area flow. Smaller QDEPHT means larger contrast between wet and dry conditions, therefore QDEPHT has a minor effect on wetland areas. QFPAR was set to 0 and QFFC to 0.2 to allow some source area flow. Table 3.3 gives an overview about all flow parameter as used in the present study.

3.1.1.3 Canopy Parameters

Canopy parameters depend on the cover type of each land use unit and primary affect transpiration. In the study area, three different main cover types are prevailing. The subdivision which was used for this study follows the three main land use units as described.

3.1.1.3.1 Forest canopy parameter

The albedo is used to calculate net radiation from solar radiation and affects transpiration and interception. Albedo (ALB in the model) values for the study site are not exactly known, but there are a number of more or less generalized values for tropical evergreen forests in the literature. Roberts, et al., (2005) cited albedo values ranging from 0.12 till 0.149 for tropical lowland Amazonian forest. Federer, (2002) recommends a value of 0.15 for evergreen tropical forest. Culf, et al., (1995) mentions values between 0.12 and 0.14 with a mean of 0.134. It should be noted that albedo values are generally calculated from point measurements, or simply result from these point measurements. In reality, a forest canopy is fairly heterogeneous and varies over time . However, it is obvious that tropical rain forests have generaly quite low albedo values, because of their high leaf area index distributed over tall, deep canopys. Such canopys are particularly effective in absorbing solar radiation. In this study a value of 0.125 was used for the forest areas.

Brook 90 requiers the maximum canopy height (MAXHT) for a year as an average of taller plants. It is possible to vary it throughout the year but as this function makes sense for annual crops is not relevant for an evergreen tropical forest and its sourroundings ans was not used in this study. Canopy heights for tropical montane forrest is differing from lowland forests. Lowland forests may reach a mean canopy height of 45 m with emergents up to 60 m whereas canopy heights of montane forests at lower elevations are around 35 m and at higher elevations even lower . The elevation of the study site (2000-2002 m.a.s.l) is in between the transition zone of lower montane and upper montane rainforests according to common defenitions (e.g. Grubb, et al., 1963; Lawton, et al., 1988; Bruijnzeel, et al., 1995 and others). There is little doubt, that the transition coincidents with the level at where cloud condensation becomes most persistent . Grubb, (1977) quotes canopy heights for lower montane rainforest between 15 and 35 m and a mean of 21.6 m , whereas Lawton, et al., (1988) states a range of between 15 and 25 m. In a study of the central Columbian cordilliera at about 2500 m.a.s.l. a mean canopy height of 25 m was meassured . Since the the three catchments are not definitely located in the lower or in the upper montane forest zone and the study area of the apporach of Veneklaas matches with the present study area fairly well (in terms of location, soil etc.), this value were used. Another parameter which is required by Brook 90 is the leaf area index (LAI or MAXLAI in the model respectively). LAI values are not unproblematic, because the measured data consist usualy of point measurements which may not represent the heterogenity of the forest sites. Especially in tropical forest with a general complex canopy structure, the common photographic measurements may underestimate the actual LAI. There is a range of LAI for tropical forest in the literatur, apart from a very high value (22) for a riverine forest in Panama, most LAI values fall between 4 and 8, whereas in forests in South America give an LAI of 6 or below . Bearing in mind, that the forests in the study area are a mixture of primary and secondary forest which may cause in a partly more sparse cover, a LAI of 5 was used.

Another factor which influence the calculation of evaporation is the surface roughness z_0 (Z0G). The surface roughness is used to estimate the turbulent transfer at the ground surface and therefore needed to calculate soil evaporation. The surface roughness is genrerally determined by fitting the semi empirical-equation of the log wind profile (3.2) under near-neutral conditions of atmospheric stability, where u_z is the wind velocity in height z, u_* the friction velocity, k the Karman constant, d the zero plane displacement and z_0 the surface rougness .

$$u_z = \frac{u_*}{k}\left[\ln\left(\frac{z - d}{z_0}\right)\right] \tag{3.2}$$

Measurements of wind profiles within tropical forests have been made only rarely but since the solar radition which reaches the forest floor can be as little as 1% of that above the forest and is therefore the limitting factor of pure soil evaopartion, this parameter may not play an evident role. However, in this approach a value of 0.80 m was used which is in the range of an generalized forest.

Since transpiration is roughly linear with maximum leaf conductance (GLMAX in the model) and values of this are poorly known , this is an uncertain parameter. Leaf or stomata conductance is an physilogical paramteter and therefore hard to estimate with more or less simple physical assumptions. It is obvious that the stomatal conductance among others depends on available energy, vapour pressure or saturation deficit respectively (physical), as well as on soil water potential (physiological, controls stomata mainly under stress conditions) . But despite there is a clear relation between increasing dryness of the atmosphere, the functional relationship between stomatal closure and increasing dryness is still not well understood. There are some studys in which stomatal conductances are mentioned (e.g. Kelliher, et al., 1995), but since there are noatble differences in the physilogy of lowland, montane and upper montane rainforest, direct adoption of such values is probably problematic.

Neverthless, the response has important hydrological and ecological implications. It means, that when the atmospheric demand is highest, there is compensatory stomata closure with the result that, on a daily basis, transpiration rates remains modest . A relatively realistsic description of evaporation from leaves and canopies is given by the Monteith version of the Penman Equation :

$$\lambda E = \frac{\Delta A + \rho_a c_p D g_b}{\Delta + \gamma(1 + {}^{g_b}/_{g_s})} \qquad (3.3)$$

Where A is the available radiative energy (W m^{-2}), c_p the specific heat capacity of air at constant pressure (J kg^{-1} K^{-1}), E the transpiration(g s^{-1} m^{-2}), D the vapour pressure deficit (Pa), λ the latent heat of vaporization of water (J g^{-1}), γ is the psychometric constant (Pa K^{-1}), Δ the slope of the saturation vapour pressure curve (Pa K^{-1}), g_b is the boundary layer conductance (m s^{-1}), g_s is the stomatal conductance (m s^{-1}) and ρ the density of air (kg m^{-3}). The stomata conductance is then often calculated from the latent heat flux or transpiration sap flux measurements by use of an inverted form of the Penman-Monteith Equation (3.4) (where β is the Bowen ratio and c_{pm} the specific heat capacity of moist air), with measured or estimated meteorological variables .

$$\frac{1}{g_s} = \frac{1}{g_b}\left(\frac{\Delta}{\gamma}\beta - 1\right) + \frac{\rho_a c_{p_m} D}{\gamma \lambda E} \qquad (3.4)$$

With given meteorological information and aerodynamic conductance it is possible to deconstruct transpiration values to yield estimates of the leaf conductance g_s . For a consistent calculation of the leaf or stomata conductance, which is a required input parameter in Brook 90, not enough data are available. However, the mentioned facts can be still useful to get a feeling for its possible range. The Bowen ratio which is required for equation (4.3) is the ratio of sensible to latent heat. For moist tropical environments it is relatively small (β generally lies between ≈10 for hot, dry environments and 0.1 for tropical oceans) because of the highly available radiative energy associated with a general availability of volatile water. With an assumed Bowen ratio between 0.15 and 0.25 (cf. Rocha et al., 2004) and a g_b range between 0.73 cm s^{-1} and 3.43 cm s^{-1} (cf. Roberts et al. (2005)) a calculation of a possible range of g_{smax} was made. Following climatic data were used for this calculation based on measurements at the meterologic station Finca La Herradura (Filandia) at 5. May 2007 10.00 am.: Relative humidity RH=95.3%, saturation vapour pressure e_s=2.36 kPa, saturation defizit D=111 Pa, temperature T=20.19°C, E=0.0116 g s^{-1} m^{-2} (mean of the day). Air density were calculated for an atmospheric pressure of 76.7 kPa at 2200 m.a.s.l and was 0.91 kg m^{-3}. This data set was choosen because of its high RH during suitable high temperature at a relatively early time of day.

The results are shown in Table 3.4. and are basically in agreement with other studys from south american rainforests. Though the smaler values seems to underestimate the actual maximum stomatal conductance. One important criteria for the occurrence of maximal stomatal conductance occurs when the saturation deficit is small but the available energy is relatively high. A reasoning of this could be too large β values. However, due to the lack of data and the generalizations that had to be made, this calculation can only be used as an estimate. Moreover, it is problematic to estimate the stomatal conductance of an entire rainforest canopy in principal. Numerous factors which may play an evident role but are difficult to measure (e.g. LAI distribution, radiaton distribution within the canopy levels, physiologic age of the leafs etc.) are limiting the actual information . In the present approach, a g_{smax} of 0.84 was used because it gained the best results.

Table 3.4: Stomata conductance g_s in dependence of different β and g_b

		g_b (cm s^{-1})					
		0.73	**1.27**	**1.81**	**2.35**	**2.89**	**3.43**
β	**0.25**	0.16	0.25	0.34	0.42	0.49	0.55
	0.23	0.17	0.28	0.37	0.45	0.53	0.59
	0.21	0.19	0.31	0.41	0.50	0.57	0.64
	0.19	0.21	0.34	0.45	0.54	0.63	0.70
	0.17	0.24	0.38	0.50	0.60	0.69	0.76
	0.15	0.28	0.44	0.57	0.68	0.77	0.84

Values of g_s are in the range of 0.16-0.84 (cm s^{-1}).

Another value which is used in Brook 90 influencing the stomatal conductance is the extinction coefficient CR. It actually plays two roles; controlling net radiation at the ground in conjunction with LAI and reducing leaf conductance in low light. Federer (2002) stated out, a value of 0.69 gives a PAR penetration on the ground of approximately 1% for a LAI of 6 and a SAI of 0,7. As mentioned above, 1% is a realistic value and with a LAI of 5 and CR of 0,6 the deviation from this is quite small.

Brook 90 requires setting the temperature range in which stomata openings are independent of, or influenced by temperature. Is the mean air temperature of the day between T1 and T2, there is no stomata closure induced by suboptimal temperature . Although these temperatures are used in the Shuttelworth adaption of the PM model, values are fairly unknown and may vary for plant species as well as for climate due to adaption. The stomata response on temperature is really difficult to separate from the vapor pressure response, therefore the values suggested and approved by Federer (2002) were used for all land use units.

Brook 90 values like maximum plant conductivity (MXKPL) and maximum length of fine roots per unit ground area (MXRTLN) which play a role when the soil water availability is limited, may not be important in the study area. Remember, the soil moisture in all land use units is generally high. For that reason the suggested values from Federer (2002) were used which are covering a wide range of vegetations.

As discussed before, root depth distribution and root biomass are an important controlling factor for infiltration behaviors in the study area. Roots generally contribute to soil porosity and almost more important, to the amount of macropores. Substantial differences between the land use units concerning the rooting depth and distribution were pointed out and are in agreement with various studies from a wide range of biomes . Besides their importance for infiltration and preferential flow, root distribution and biomass are an important factor for water uptake from plants and therefore for transpiration. Root distribution depends on numerous issues, e.g. soil density, water availability, plant condition and so on another numerous environmental issues but are not inevitably limited to the revealed ones. In general it is difficult to quantify the respective importance on a local scale . Schulze et al. (1996) found, that besides the fact that the main concentration of roots is in the upper soil layers, the minor amount of deep roots ensures the water supply of plants in dry periods or are even the main way plants cover their requirements. Consequently, maximum rooting depht is an important factor for transpiration in general because the occurrence of only a relatively small amount of deep roots can be responsible for a significant water uptake from deep soil layers. Contrariwise one can consider that a high percentage of root mass in the upper soil does not obligatory contributes to higher transpiration rates related to comparable soils with less root mass in the upper horizons. Unfortunately the lower boundary that separates soil from the material underneath is often difficult to define. In some sites soil is clearly defined by its boundary at solid bedrock, but in other sites soils grade into the regoliths underneath which can be very deep especially in humid and tropical climates where the studies deriving root data are additionally less than in most other regions . For that reason the definition of the root distribution in the study site is fraught with uncertainty, particularly as the soil characteristics for the study area are not known in detail. To face such problems Jackson et al. (1996), as well as Schenk et al. (2002), summarized average root distributions for various biomes including tropical evergreen forests, tropical grassland and temperate grassland. The values for tropical environments of Schenk et al. (2002), are slightly lower with a median rooting depth for tropical evergreen forests of 15 cm. Because of the relatively wet soils suggesting no need for deep rooting this value was used. Calculating the relative root density (ROOTDEN,f) with depht was made in combination of this value with the equation (3.5) suggested by Federer et al. (2003), which is in fact a derivation of the eqaution given by Jackson et al. (1996) and will be used later on:

$$f = 1 - 0.5^{z/h} \qquad (3.5)$$

Where f is the fraction of roots above depth z and h is the half-depth or depth at which f=0.5 . Because Eq. (4.4) approaches f=0 asymptotically, the definition of an effective rooting depth, D_r , is arbitrary. A D_r defined by f= 0.99 or the depth that includes 99% of the roots, which is 6.64 * h, is specified here as D_r99 . Table 3.5 shows the values derived from this calculation.

Table 3.5: Relative root distribution (forest) over to the depth that includes 99% of the total length, Dr99. The half-depth h from Eq. (3.5) is 150 mm.

Soil depht (mm)	Rootfraction above z
100	0.37
200	0.23
300	0.15
400	0.09
500	0.06
600	0.04
700	0.02
800	0.01
900	0.01
1000	0.01

The first 20 cm of the soil is assumed to be a litter layer (L layer) , which does not contain a remarkable amount of roots. Since the model will distribute the root fractions automatically over the soil layers, which will be discussed in later, the first 200 mm were set to 0.

3.1.1.3.2 Grassland canopy paramter

There are various references about tropical grasslands but many of them deal with grasslands in the context of savannas. The grassland surfaces in the study area have been subjects of land conversions from tropical evergreen forests to more or less unmanaged pastures. At least some areas, were cultivated as plantations before they were used as pastures. All in all the concept of tropical savannas does not match the conditions in the study site where precipitation (long term annual mean) is approximately 2990 mm a^{-1}. Note, the definition of savanna is not absolutely clear, since this classification is used in geographic, physiologic and climatic context in which a moist savanna exist in climates with an annual precipitation of 1000-1500 mm and 7-8 humid months. Therefore, since no direct data from the study area was available and no values of studies with an explicit comparable background the parameters which are sufficient for grasslands in general were used and/or extended if reasonable.

It is evident, that pastures or grassland surfaces do not have albedo values as low as for forests. There are numerous authors reporting a notable albedo increase after forest clearing in tropical areas (e.g. Berbet, et al., 2003). Dirmeyer et al. (1994) reported changes of local seasonal circulation patterns due to change of vegetation alone but as well because of albedo changes. In their study they stated out, that the albedo after a forest to pasture conversion can be about 0.09 above the original value. Culf et al. (1995) found an average values of 0.18. In other studies this increase is slightly lower and in the range of +0.03-0.08 . The lower values are probably more suitable because secondary succesional vegetation are likely to attenuate the effects of the forrest clearing and the mentioned values are annual means. The albedo of tropical pastures can vary with the season because of bleaching out in dryer periods . But because of the relative high soil moisture in the study area throughout the year, this effect is expected to be relatively low. There are a few other mechanism that probably influence seasonal albedo variations in tropical grasslands (e.g. height, leaf angle; for further information see Berbet, et al., 2003) but as Brook 90 does not allow to vary the albedo over the year, these were ignored. Albedo values between 0.125 and 0.21 seems to be reasonable.

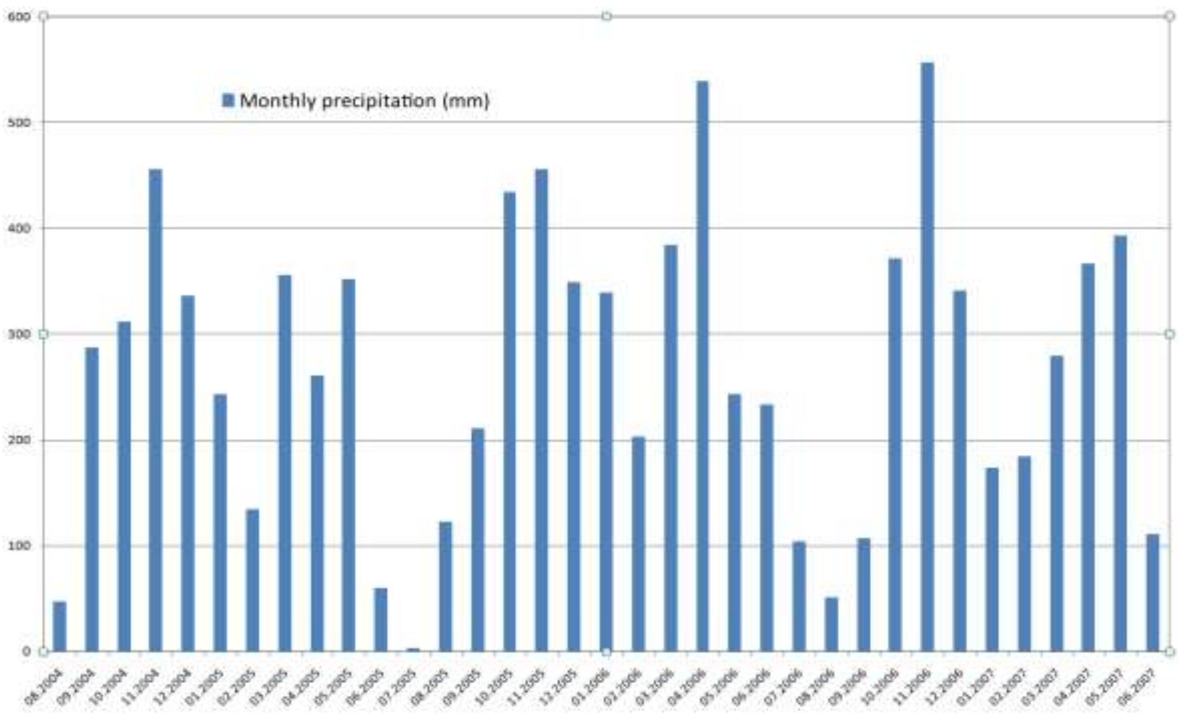

Figure 3.2: Monthly precipitation for B1 catchment.

Other than for forests, the maximum canopy height for pastures varies throughout the year. This variation is usualy corelated with the saisonal climatic variations at the site. Acording to Kalma et al. (1972) most growth occurs in periods which follows rainy periods. Following Kalma and in reference to Figure 3.2, most growth can therefore be expected to occur in the period from June till August and in a second period between January and February. This variations does potentially not reflect the actual situation at the study site and its influence on transpiration is hence a misinterpretation. As the used variations are relatively small (between 40 and 60 cm) this does not have an significant effect. Model runs with and without seasonal growth variations did not show notable differences.

Seasonal LAI variation of tropical pastures between 1 and 3 is common in studies related to tropical pastures . Because it is not known how LAI varies over the year at the study site (e.g. no information about plant species, bloom or not etc.), a maximum LAI of 2 was assumed for the grassland sites which is in agreement with the cited researches.

According to Federer, (2002) the surface roughness below canopy is aound 0.01 m for grasslands. Due to a lack of better knowledge and to the fact that this parameter doesn´t matter much (Federer 2002) 0.01 m was used for the grassland setup.

As mentioned before, a relatively important parameter in terms of transpiration is the leaf or stomata conductance. Contrary to the forests, grassland transpiration is generally lower which is mainly a result of limited rooting depth and lower LAIs. Therefore this value is probably somewhat less important here but it still has an evident impact on the transpiration. An estimation wit equation (4.2) and a g_b of 2.5 cm s^{-1} , which is acceptable for temperate grasslands (Kelliher, et al. 1993), yields values from 0.44-0.7 cm s^{-1}. This is in major agreement with the respective literature where values between 0.46 cm s^{-1} and 0.77 cm s^{-1} for temperate grasslands are common (Kelliher,et al.1993, Kelliher, et al. 1994). The difference in terms of maximum stomata conductance between temperate grasslands and grasslands of other climates (except tundra) is generally negligible . A g_b (GLMAX) of 0.7 cm s^{-1} seemed to fit the needs sufficiently good.

MXPL, Cr (which must be higher for short vegetation covers, since the canopy is denser) and MXRTLN were used as suggested by Federer (2002). A discussion about the selection of this parameters can be found in chapter 3.1.1.3.1. An overview of all canopy parameters which were used for modeling can be found at the end of chapter 3.1.1.3.3.

Rooting depth of tropical pastures is generally less than that of moist tropical forests whereas the root length density in the upper 50 cm of the soil is up to three times higher . As referred before, tropical savannas and the dedicated rooting distributions seemed not to be useful for this approach. Schenk, et al., (2002) reported rooting dephts and distributions of such biomes to equal or even exceed that of tropical evergreen forests, which is not credible for the climatic conditions of the study site. The particular consideration of grasses, yields a slightly different picture. With a D_r50 of 14 cm and a D_r99 of 93 cm (D_r95 of 60 cm), grasses appears to be more functional. This values were calculated with the model and data given by Jackson, et al., (1996), which is:

$$Y = 0.5 - \beta^d \qquad (4.5)$$

Where Y is the cumulative root fraction (a proportion between 0 and 1) from the soil surface to depth d (cm) and β is the fitted "extinction coefficient which is 0.952 for grasses in average. The relative root fractions f as used are thus (Table 3.6):

Table 3.6: Relative root distribution (pastures) over to the depth that includes 95% (rounded) of the total length, Dr95. The half-depth h from Eq. (4.4) is 140 mm.

Soil depht (mm)	Rootfraction above z
50	0.22
100	0.17
150	0.13
200	0.10
250	0.08
300	0.06
350	0.05
400	0.04
450	0.03
500	0.02
550	0.02
600	0.01

3.1.1.3.3 Wetland canopy parameter

The wetlands of the study area are poorly known in terms of plant specific parameters. A wetland inventory was done by Roa-García (2009), though under an underlying objective which fulfills the needs of the present approach only partly. The comprehension of wetlands is complicated and the mechanisms are barely comparable among each other . It is known that parts of the bigger wetlands at the study site do have an open water body throughout the year but neither actual portions, nor the cover (e.g. density, cover type) of that and/or the remaining area is familiar. This information is important for estimating the surface albedo and therefore the net radiation. But since this is not the only driver that influences transpiration it is problematic to adjust such values till the model produces pertinent results. As an example, it is possible to adjust transpiration in the respective context mainly with albedo, but as a consequence rooting, LAI and other plant specific parameters could probably not be used in a realistic way or do not credibly correspond to assumptions of the albedo. However, Eleocharis maculosa (Vahl) was found to be the dominant plant in all of the studied wetlands with a covering of roughly 20%, whereas the total plant covering is given between 78% and 51% . In BB catchment the total cover accounts for 51% of the surface. Since BB catchment is the catchment with the largest portion of wetland area (6.1%) and it is consequently most affected by wetland flows (Roa-García and Weiler, 2010) the BB wetland inventory was used as a benchmark for the wetland setup.

The estimation of the surface albedo for wetland areas is additionally problematic because albedo has generally large diurnal and seasonal variations. This is a consequence of different irradiation angles during the season as well as on diurnal basis. It is even more important for moistened surfaces and open water bodies than for most other surfaces. The degree of plant covering plays again a major role in this context. However, albedo for open water is given by Federer (2002) with 0.1. Since the wetland surfaces are not purely open waters, a value of 0.15 might be realistic. In the floodplains of the upper Rhine basin a mean albedo of the same magnitude was found. The surface roughness is also expected to be relatively low and was set to 0.001 m. since

MXPL and MXRTLN were used as suggested by Federer (2002) for grass. A discussion about the selection of these parameters can be found in chapter 3.1.1.3.1.

Table 3.7: Relative root distribution (wetland) over to the depth that includes 95% of the total length, Dr95. The half-depth h from Eq. (4.4) is 134 mm.

Soil depht (mm)	Rootfraction above z
50	0.23
100	0.18
150	0.14
200	0.10
250	0.08
300	0.06
350	0.05
400	0.04
450	0.03
500	0.02
550	0.02
600	0.01

Cr should be lower than for pastures because Elocharis appears to be much less dense. According to this Cr was set to 0.45 which is slightly below coniferous trees. Maximum leaf conductance is assumed to be relatively high as there is no need for wetland plants to minimize transpiration due to limited water supply. For Juncus effesus L., which is the plant with the second largest portion, g_{smax} between 0.49 cm s^{-1} and 1.05 cm s^{-1} were found . The latter is indeed a quite high value. Axonopus compressus (Sw.) is probably in the same range since it is classified as a wetland plant with water demand even higher than Juncus effesus. Axonopus compressus is the plant with the third most frequent appearance, whereby it is the most frequent plant in B1. As provided in URL1, the rooting depth is around 30 cm for Axonopus compressus and 60 cm for Juncus effesus respectively. Canopy heights are between 30 cm and 2 m (for Axonopus compressus and Juncus effesus). For Elocharis maculosa no data were available. Considering that the taller Juncus effesus does not occur in BB, MAXHT was set to 70 cm, which probably over estimates this roughness relevant value. With the same background, the median rooting depth f=0.5 was assessed with 134 mm. This is arbitrary but in a possible range and gains a Dr95 of 600mm. The distribution of f is shown in Table 3.7. MAXHT was varied over the year with minimum heights at the end of the dry season (August).

Table 3.8: Canopy parameter as used in this approach and discussed above. The values in the last three rows are without special reference, which means that them are estimated and/or used as proposed by Federer (2002). MXKPL, PSCIR, CS and the temperatures does not vary with landuse.

Landuse	ALB	Z0G (m)	MAXHT (m)	MAXLAI	GLMAX (cm/s)	LWIDTH (m)	CR	MXRTLN (m/m^{2})
Forest	0.125	0.8	25	5	0.84	0.1	0.6	3000
Pasture	0.2	0.01	0.6	2	0.7	0.01	0.7	1000
Wetland	0.15	0.001	0.7	2	1.1	0.007	0.45	1000
	MXKPL (mm/dMPa)	PSCIR (MPa)	CS	TL (°C)	T1 (°C)	T2 (°C)	TH (°C)	FXYLEM
Forest	8	-2	0.035	0	10	30	40	0.5
Pasture	8	-2	0.035	0	10	30	40	0
Wetland	8	-2	0.035	0	10	30	40	0

3.1.1.4 Soil parameter

In the latter it is specified what parameters are used for the soil setup and how the parameter values were chosen or calculated. Table 3.9 at the end of the chapter will give an overview about all soil parameter as used in this study. Except for the wetlands, where Roa-Garcia (2009) mentioned some more detailed values, average soil thickness was assumed to be 1.5 m.

3.1.1.4.1 Forest soils

As mentioned above, the litter layer in tropical evergreen forests is assumed to influence the water balance . Mean annual litter fall amounts were reported to reach 7.03 tons ha^{-1} at Colombian montane rainforest sites . As reported for Amazonian forest, L-layers thickness can reach 30 cm and more . Litter does store water and what is almost more important, litter has high infiltration capacities and is therefore preventing or at least retarding surface runoff even if precipitation intensity is high. In this study the L-layer was treated like a porous medium. This is something like a 'continuum approach', where the litter is treated as soil and where adjusted soil features are used for the litter layer. Litter layer thickness between 16 and 30 cm was used as layer thickness of the additional top soil layer in the forested areas. In Marin et al. (2000) it was stated that the mean permanent storage capacity is between 4.6 mm and 16.3 mm. The lower end does not seem applicable to the present study because of the loose structure of the related canopy. The termed storage capacity is related to a condition which could be defined as field capacity, although it is not. Marin et al. (2000) first saturated the litter layer manually covered it to prevent evaporation and weighted layer samples after 24 h of drainage. However, the temporary storage capacity might be much higher. It should be noted that the continuum approach as used here, is not physically correct. A litter layer does likely not act like a typical soil. A soil moisture retention curve would not show classical course which could indicate a behavior like clays or a sands respectively. This is due to the fact, that the water storage capacity is not determined by capillary water held in the gaps created between litters but by the adhesion water held by each litter surface . Therefore, one should separate between maximum storage capacity and an 'intercepted storage capacity'. The maximum storage capacity depends on litter mass (more than on layer thickness, due to the 'surface-storage-relation') and the intercepted capacity on rainfall amounts and intensities because the structure of a litter layer (consisting of more or less wizened single leafs) would prevent for watering all areas uniformly. This implies that the 'current' maximum storage capacity, which is the maximum intercepted capacity for a given storm event, is variable in time. However, litter layers have an impact on infiltration and flow retention. While the simulation of the hydrologic litter layer behavior is not purpose of this study its influence is probably not negligible. To include the potential impacts of the litter layer the previously mentioned 'continuum approach' was used with a mean storage capacity given by Marin et al. (2002) of 16.29 mm for a litter layer of 9.81 kg m^{-2}. The related layer thickness was 16.36 cm which results in a storage capacity or soil porosity respectively of 0.1 cm^3 cm^{-3}. Although this is a relatively small amount, one should consider that this is additional porosity on soil surface. Besides that and by reference of the previous advisements, designing the litter layer in such a way may over or underestimate the real retention effect. Hydraulic conductivity at field capacity was set to 5 mm d^{-1}. This is arbitrary but considers the low hydraulic conductivity for organic surfaces for leafs and humus as well as a quicker component through gaps in the litter layer. For a discussion of hydraulic conductivities depending on a high fraction of organic components see chapter 3.1.1.4.2.

The setup for the remaining 1.5 m of the soil profile, were mainly done by use of values given by Roa-Garcia (2009). The total porosity of 0.76 cm^3 cm^{-3} was distributed over the soil depth and a slightly reduced with that. Same was done for moisture content at field capacity (0.61 cm^3 cm^{-3}) as well as for hydraulic conductivity at field capacity (k_{fk} in the following).

In the absence of measured data, Federer (2002) suggests a k_{fk} of 5 mm d^{-1} and showed that this is an appropriate value for a large range of soils of different texture. However, in this The in this study used lower value of 4.37 mm d^{-1} (mean throughout the soil profile) was to consider the relatively high content of organic matter in the soils. Saturated hydraulic conductivity in forest soils could probably overestimate the hydraulic conductivity at any unsaturated state, because the measurement of saturated hydraulic conductivity in these soils accounts for macropore and pipeflow. Macropore and pipeflow is assumed to be negligible at unsaturated state as field capacity is and a hydraulic conductivity estimation based on saturated conditions would reversely overestimate k_{fk}.

The input parameter BEXP is the exponent b in the Brooks and Corey equation as given by Clapp and Hornberger (1978) and mostly affects the sharpness of curvature and the slope of the θ-log-ψ relation. With:

$$\log\left(\frac{\Psi_{\text{initial}}}{\Psi_{\text{field capacity}}}\right) = -b * \log\left(\frac{\Theta}{\Theta\text{field capacity}}\right) \qquad (3.7)$$

It can be derived as the negative slope of a linear regression between log-ψ and log-θ . Figure 3.3 and Figure 3.4 show the log functions, the linear regressions as well as the soil water retention curves in the more common semi-log way. Since measured data for natural forests as well as for plantation/secondary forest were available, the forest soil parameter setup was specified for these two land use types. This mostly affects B1 catchment (17% of the catchment area), whereas for B2 and BB the plantation forest proportion is below 1% and 5% respectively. This does not affect the other parameters (e.g. canopy) since no information about vegetation types and or proportions of this vegetation types were available.

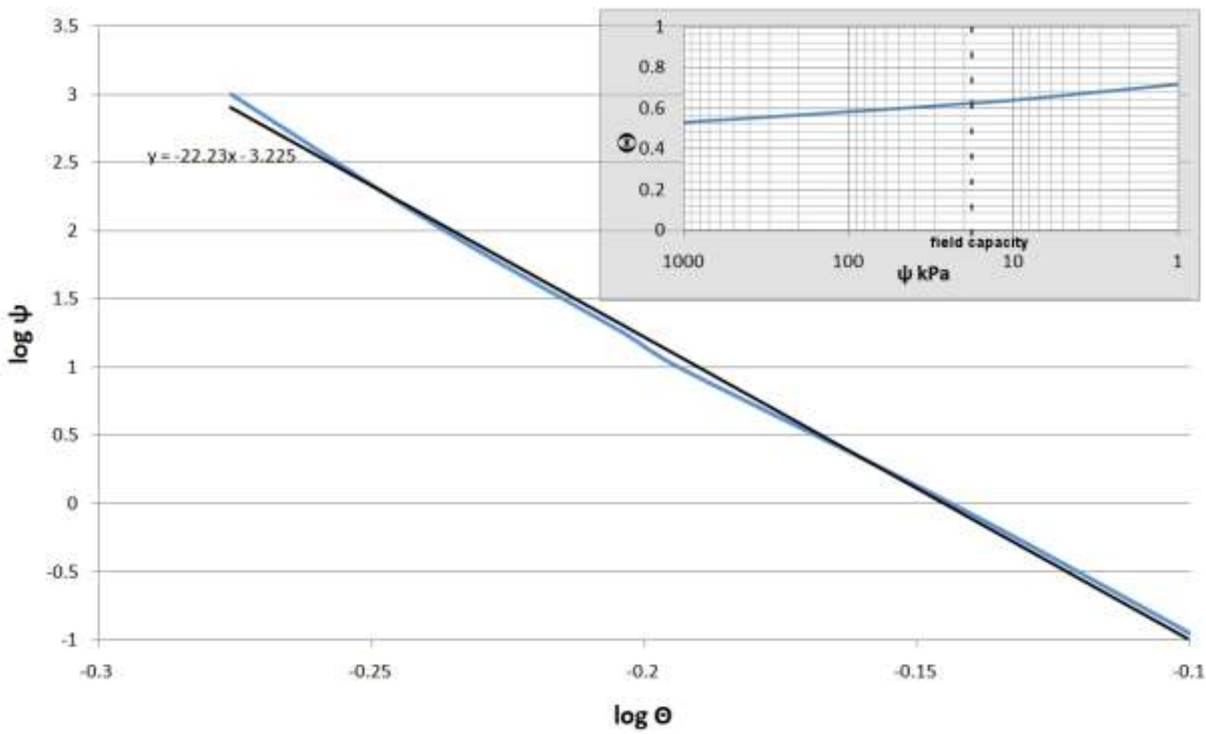

Figure 3.3: log-Ψ log-Θ relation for the natural forest sites with linear regression (black line). The gray box shows the more common soil water retention curve with Θ cm^3 cm^{-3} (moisture content) and Ψ in kPa (soil water suction). Field capacity (dashed line) is 0.61 cm^3 cm^{-3} at 18 kPa.

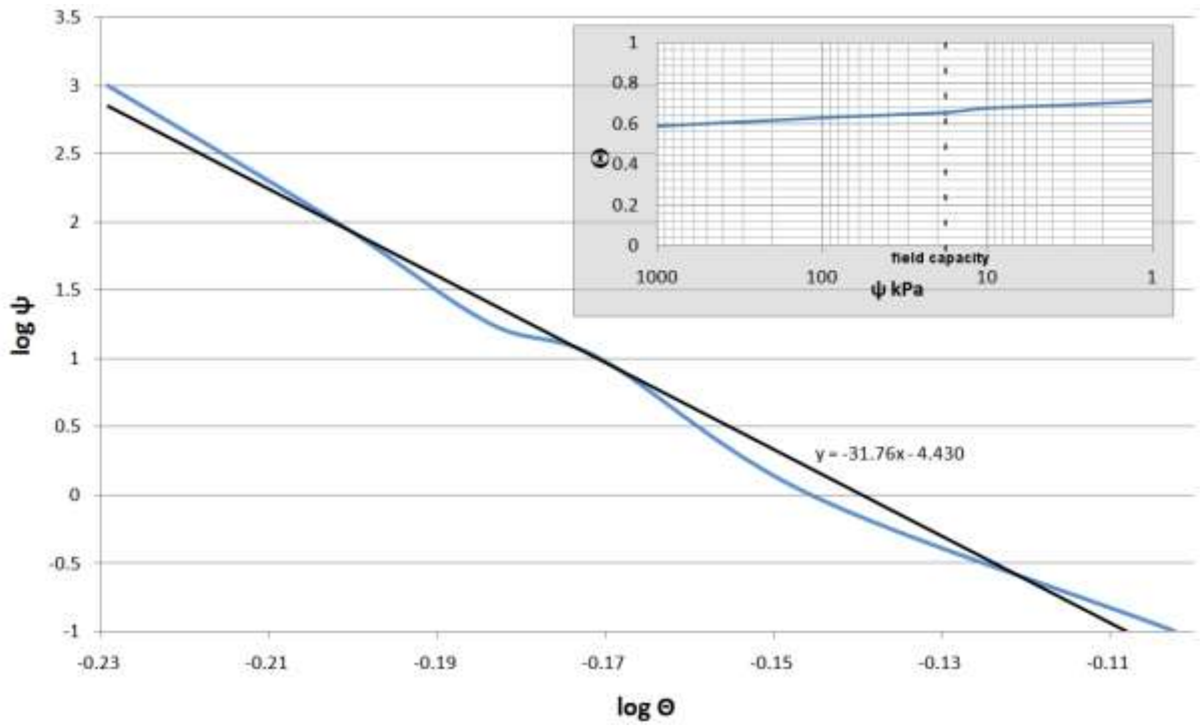

Figure 3.4: log-Ψ log-Θ relation for the plantation forest sites with linear regression (black line). The gray box shows the more common soil water retention curve with Θ cm^3 cm^{-3} (moisture content) and Ψ in kPa (soil water suction). Field capacity (dashed line) is 0.64 cm^3 cm^{-3} at 18 kPa.

3.1.1.4.2 Wetland Soils

Wetland soils do have a generally high content of organic matter. The volumetric organic matter content for three selected wetlands, which was assumed to be representative for the wetland of each catchment , is between 20% and 38%. The decomposition rates are relatively low, which is probably a consequence of the lower mean temperature in the study area in relation to other tropical wetlands . The variations in wetland morphology and ecology between the three selected wetlands as reported by Roa-García (2009), indicates that the characteristics of these wetlands are hard to generalize in terms of modeling. Since total porosity for BB wetland (86%) is between that for B1 wetland (79%) and B2 wetland (91%) and almost similar ratio applys for organic matter content (20% - 33% - 38%), BB wetland seems to be somewhat in the middle of at least some relevant properties. Taking this into account, plus the fact that BB catchment has the largest amount of total wetland, BB catchment was used as reference for the input paramter selection. Unfortunately there was neither a soil water retention (Ψ-Θ-relation) curve nor bulk density values and much less hydraulic conductivities available. Despite the organic matter content, no additional information about soil texture (e.g. clay or sand portion respectively) were on hand as well. It is evident, that higher amounts of decomposed organic matters generaly lead to very low hydraulic conductivities, which is in turn an important feature for wetlands, as it prevents the wetland body for drying out .

Due to the generally high content of organic matter and due to the slow decomposition rates in the study site wetlands, the bulk density was assumed to be significantly lower than for the other landuse types. Bloemen (1983) applied empirical relations between bulk density and hydraulic conductivity in soils with more than 30% of organic matter, based on the Brooks and Corey equation (3.8).

$$k(\psi) = k_s \left(\frac{\psi_a}{\psi}\right)^b \quad \text{for } \psi > \psi_a \qquad (3.8)$$

where k_s is the saturated hydraulic conductivity (cm d-1), k(ψ) is the vertical unsaturated hydraulic conductivity (cm d-1), ψ_a is the pressure head (cmWS) and b is slope of the k(ψ)-relationship during desorption for $|\psi|>|\psi_a|$.

The empirical equations from Bloemen (1983) with dry bulk density ϱ_b for less decomposed fen peats are as follows:

$$k_s = 0.00266\varrho_b{}^{-3.625} \qquad (3.9)$$

$$b = 2.54 - 2.42\varrho_b \qquad (3.10)$$

$$\psi_a = -4.16\varrho_b{}^{1.12} \qquad (3.11)$$

Assuming a bulk density of 0.2 g cm^{-3} which is below the bulk density of the forest soils in the study area (0.7 g cm^{-3}) and on the upper limit of what is given in literature for sedge fen peats , a k_s (cm d^{-1}) of 0.91, a b (or BEXP, which is the parameter name in Brook 90) of 2.06 and a ψ_a of -6.73 kPa (-68.59 cmWS) can be derived. Using equation (3.8) with ψ_{fk} of -18 kPa (183 cmWS) at field capacity (which is a mean value for tropical soil (Brady and Weil, 1999) and in the general range of field capacities overall) and the values derived before, hydraulic conductivity at field capacity is k_{fk}=0.26 cm d^{-1}. Note this does not fulfill the exact requirements for field capacity as defined by Federer et al. (2002). Since no measurements for the study site do exist, much less for the Brook 90 field capacity definition, this issue was ignored. Test model runs gained unrealistic high storm peaks and therefore k_{fk} was increased. The calculated k_{fk} is too high compared to reference values of Bloemen (1983). Considering that the correlation coefficient r in Bloemens study for hydraulic conductivity was -0.64 and the statistical coherence is relatively low (for a bulk density of 0.2 g cm^{-3}, k_s fluctuates between approximately 0.04 cm d^{-1} and 6 cm d^{-1} with a second cluster within the 0.95 confidence interval at ca. 2 cm d^{-1}) a k_{fk} of 0.26 cm d^{-1} could be realistic. Soil moisture content at field capacity was set to 61%, which is the average value for the forest sites as stated by Roa-García (2009).

Due to the lack of better knowledge the soil layer setup for the wetlands was reduced to a single soil layer, which ignores likely decreasing conductivities and raising bulk densities with depth as well as more advanced decomposition levels of the organic matter. The layer thickness was set to 2400 mm, which is solely oriented on the maximum wetland depth (2700 mm) as given by Roa-García (2009).

3.1.1.4.3 Grassland soil

Soil parameter for the grassland sites were divided in three layers, each with a thickness of 500 mm to allow a decrease of hydraulic conductivity and total porosity with depth as well as a slight increase of the stone fraction. Values for total porosity and water content at field capacity were used as given by Roa-García (2009) and distributed over depht. ψ_{fk} is -18 kPa according to the same basis as for the grassland and forest sites. The exponent b or BEXP was derived from a log-Ψ log-Θ relation in the same way as described for the forest soils. The log-Ψ log-Θ relation, the linear regression as well as the Ψ-Θ-relation in a more common way are shown in Figure 3.5. According to this BEXP was set to 23.51. k_{fk} was set to 4 mm d^{-1}. This is arbitrary but no better value is available. Hydraulic conductivity was slightly decreased wit depth, starting at 4 mm d^{-1} for the first 500 mm of soil and ending at 3.6 for the last 500 mm.

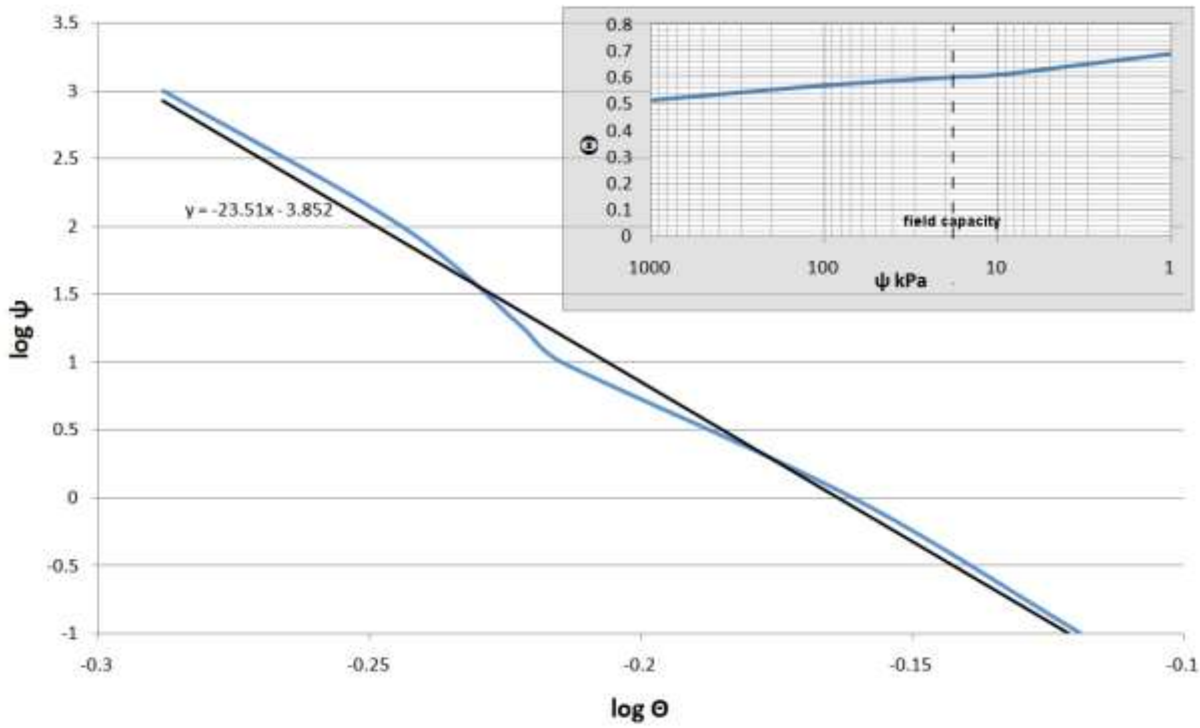

Figure 3.5: log-Ψ log-Θ relation for the grassland sites with linear regression (black line). The gray box shows the more common soil water retention curve with Θ cm^3 cm^{-3} (moisture content) and Ψ in kPa (soil water suction). Field capacity (dashed line) is 0.6 cm^3 cm^{-3} at 18 kPa.

Table 3.1: Soil parameter for the three land use units in the study site. Secondary forest is deemed as natural forest, except for the soil parameter.

	Layer Thickness (mm)	Stone fraction (cm^3cm^{-3})	Soil water potential at field capacity (kPa)	Water Content at field capacity (cm^3cm^{-3})	Water Content at saturation (cm3cm-3)	BEXP	Hydraulic Conductivity K at field capacity ($mm\ d^{-1}$)
Forest	160	-	-7	0.1	0.5	5	5
	500	-	-18	0.65	0.8	22.23	5
	500	0.1	-18	0.63	0.78	22.23	4.3
	500	0.15	-18	0.55	0.7	22.23	3.8
Secondary Forest	160	-	-7	0.1	0.5	5	5
	500	-	-18	0.68	0.74	31.76	5
	500	0.1	-18	0.66	0.72	31.76	4.3
	500	0.15	-18	0.58	0.64	31.76	3.8
Grassland	500	-	-18	0.72	0.72	23.51	4
	500	-	-18	0.71	0.71	23.51	3.8
	500	0.15	-18	0.69	0.69	23.51	3.6
Wetland	2400	-	-18	0.61	0.86	2.06	2

3.2 Input Data

Meteorological and hydrological time series for the three catchments were provided by Roa-García (2009). The precipitation was meassured by data logging rain gauges where one was placed for each chatchment. Precipitation time series were recorded from October 2004 until May 2007.

Runoff measurements were made with three AquiStar PTX2X Smart Sensors which are submersible pressure/temperature sensors and data loggers combined in one unit that provides net pressure (referenced to atmospheric pressure) within an accuracy of ± 2 mm for pressure. Water level was recorded every 15 min from June 2005 until May 2007. The recorded water level was transferred through stage-discharge relationships for each of the three sites. To derive this relationships, separate discharge flow meassurements were made for a wide range of water levels by use of a current meter. The water level series were convertetd into flow meassurments with stage discharge releations by 62, 44 and 50 discharge measurements for catchment B1, B2 and BB respectively. For stage discharge realtionships and detailed info about the technical background of these measurements see Roa-García (2009).

Climatic data such as temperature, global radiation wind speed and relative humidity were measured at one point located in BB catchment using dedicated logging devices for the several variables (HOBO Pro temperature sensor, HOBO relative humidity sensor, Onset Silicon Pyranometer Smart Sensor and a Totalizing anemometer for wind speed measurements). Temperature, relative humidity and solar radiation measurements were done every 10 min and 15 minutes for radiation respectively. For detailed info about these measurements see Roa-García (2009).

Reviewing of the time series revealed partly significant gaps in these series which needed to be completed and/or obstructed the use of the entire series. First of all, precipitation and runoff time series did only meet for the period between June 2005 and May 2007 which implies that only one entire year was continuously observed. Besides that, solar radiation time series started at 18th of November 2005 which limits the covered time frame additionally. It was tried to stretch the solar radiation series by use of a linear regression analysis with temperature as well as by multiple linear regression analysis with temperature and relative humidity, since this parameters are more or less directly related to solar radiation. Since temperature usually drags behind solar radiation it was also tried to rearrange the temperature and radiation series stepwise (within the 15 minutes recording interval) and obtain the correlation coefficient for each step (same was done with a moving average of 11 days). The calculated correlation coefficients did not show any advancement and remained relatively small below 0.7. Coefficient of determination between the series derived from regression and the available radiation data fluctuated around 0.5. Hence it was decided to use only the existing series within the overlapping window. Daily radiation was calculated then in MJ m^{-2} d^{-1} from the 15 minute measurement interval.

3.2.1 Vapor Pressure

To obtain the average vapor pressure saturated vapor pressure e_s was calculated for each of the 15 min temperature intervals by using the Goff-Gratch equation (3.12). This is the WMO suggested method for transferring temperatures to vapor pressure . Actual vapor pressure was calculated using the relation showed in equation (3.14).

$$e_s = e_{st} 10^z \qquad (3.12)$$

where:

$$Z = a\left(\frac{T_s}{T} - 1\right) + b * \log_{10}\left(\frac{T_s}{T}\right) + c\left(10^{d\left(1-\frac{T}{T_s}\right)} - 1\right) + f\left(10^{h\left(\frac{T_s}{T}-1\right)} - 1\right) \qquad (3.13)$$

where Ts is the absolute temperature at steam point, T the absolute air temperature, e_{st} is e at steam point and a,b,c,d,f are constants .

$$e = RH * \frac{e_s}{100} \qquad (3.14)$$

where RH is relative humidity (%), e is vapor pressure (Pa) and e_s is saturation vapor pressure (Pa).

The RH series had several data voids. Firstly it was tried to close these gaps by using linear regressions between relevant months in previous years, but the correlation analysis between related months did not show a strong connection. Same was evident for correlations between temperatures of related periods in previous or later years and RH. So it was decided to use a simple linear interpolation for the daily means to complete the data voids. Data voids in the preselected period were present for 16.09.2006-25.09.2006 as well as 23.09.2006-17.10.2006. Additionally several negative values of single measurements of the 10 min intervals as well as for entire single days were present. If this was so, they were excluded from the calculation of the daily mean or in the case of missing days, completed by use of the previous day average.

3.2.2 Wind speed

The wind speed series had gaps or negative values for single disjointed days (six days overall). Since wind has generally a high variability, can anyways not be assumed to be homogeneous within space and did not show a strong seasonality at study site, the annual mean wind speed was used to complete this gaps (2.85 m s^{-1}). Given this average wind speed is used to calculate evaporation on daily basis, this will not cause a relevant deviation for more than the related days.

3.2.3 Temperature

Temperature time series had more or less the same voids like RH series (what by the way made regression analysis between these parameters to complete the void of the respective other questionable). Less in this case means that for the model T minimum and T maximum is required and data voids of single records did not matter much because minimum and maximum for the respective day could still be extracted. Even those might not be the real minima and maxima respectively, the deviations from those should be minimal. For other days minima and maxima T could be extracted without any restrictions.

3.2.4 Precipitation

More problematic are data voids within the precipitation series because they are not obvious. The precipitation measurement was done by an automatic tipping bucket and presented in a .txt file including rows for dates such as month, day, year, hour, minute and second which are all related to single tips. Therefore, the missing of a single day or a cycle of days in general means that there was no rainfall. By calculating the daily mean out of these single tips, a missing day would give an average precipitation amount of 0 for this particular day and would not attract any attention, unless it is within a cycle of high intensities and would therefore mean an abrupt break. Some of such anomalies might be identified by comparing runoff and precipitation time series where others may not because they occurred in a descending cycle of the hydrograph and are not intense and large enough to produce an immediate instant and therefore visible reaction within the curve shape.

This is discussed here, because such a data void was identified at the beginning of 2006 within the BB precipitation time series, lasting for probably 31 days (12.01.2006-12.02.2006). Observed runoff showed significant peaks which were not present in observed precipitations as well as in the model but within the precipitation series of the other catchments. This obvious gap in the data was then completed by applying a linear regression between the precipitation series of B1 and BB for which the correlation coefficient was higher (r=0.9) than for the series of B2 and BB. The coefficient of determination between the regression and observed BB precipitation R^2 was 0.8 where the regression was applied through 0. The time series for the other catchments did not show any irregularities what however may or may not mean that there are not minor voids which are not obvious according to the discussed context. For all precipitation series daily totals were calculated within the defined period.

To account for interception losses, the monthly mean of daily hours with rainfall were derived where it was not differentiated for what time the event actually lasted. Rather only hours with or without records where counted.

4 Results

4.1 Modeled catchment runoff

In the following paragraphs the modeled results for the three catchments will be shown. A graphical overview about the relative deviation distributions for all catchments is given in chapter 4.1.4.

4.1.1 B1 Catchment

4.1.1.1 Daily graph

Figure 4.1 shows the modeled and the observed daily runoff (Q) for B1 catchment. The included bulk chart on top represents the daily precipitation sum in mm. Left axis is the Q scale in m³ whereas the right axis is in mm and is related to precipitation (P). Starting with first of January 2006 (01.01.2006) in the season with relatively low precipitation and ending at the 18th of may 2007 (18.05.2007) which is almost the end of the season where rainfall peaks the second time.

The first peak flow of the model graph meets the observed one almost exactly but the descending sequence decreases slightly too sharp. In the following period the modeled data seems to overestimate all high and low peak flows as well as the low flows in general. To take one case in point, the difference between the measured and observed peak flow at 05.02.2006 is as high as 17792.12 m^3d^{-1} or in other words 52.7%. The difference in Q at the low point of 27.01.2006 amounts to 4652 m^3d^{-1} which is more than 100% relative deviation. However, the time lag between the observed and the modeled peaks and lows is null or minimal. In the middle of March 2006 the discrepancy between the modeled and observed graph drops down a bit. Also the model and the observed flows are in better agreement during the short rainy season (April-May), although the model is underestimating the most peaks. Besides that, the peakflows at 09.03.06, 01.04.06, 06.04.06 and 20.04.06 are still significantly to large (35.4%, 62%, 41.9% and 23.6% respectively). The low at 07.05.2006 is overestimated by 44.5% which is 4538.6 m^3d^{-1} in total. Even though, for the period April till the end of May 59% of the modeled Q (Qm hereafter) deviate less than 20% from the observed (Qo hereafter) ones (at least 32% deviate less than 10%). For the drier period January-February only 30% of all values have a deviation of less than 20% (highest deviation at 28.01.2006 with 150%). The median of the deviation in this period is 50.8%.

As seen in Figure 4.1, the difference in total monthly rainfall between period January-February and April-May is not distinctive. At least for May 2006 the rainfall contrasts more in terms of intensity and temporal distribution than in total amounts. Total precipitation for May is 243.6 mm and for January-February 339.6 mm and 202.8 mm respectively. Total for April is 538.8 mm and for March, which in the long-standing mean does neither belong to the rainy nor to the dry season 384 mm.

For the dry period, starting with the declining curve at 15.06.2006 and ending with ascending curve at 11.10.2006, the curve seems to fit the peaks and lows better although the modeled Q generally overestimates the observed Q. This is changing at 25.08.2006, whereupon the modeled graph is below the observed one. Despite the appearance, the discrepancy between Qm and Qo is still significant. Till this date, the curve shape of the modeled graph is too smooth compared to the observed one. However, except 13.07. and 15.07. (1.8 mm and 0.2 mm, respectively), there was no precipitation input recorded (26.06.2006-19.07.2006). The discrepancy for the entire low flow period varies strongly with a maximum at around 25.07.06 (400%). 34% of Qm have relative deviations of less than 20% from measured Q during the entire low flow period, 58% of Qm deviates less than 40% from Qo, whereas 8% have relative deviations of more than 100% The low flow period or dry season is interrupted by several small precipitation events which accumulate towards the end. The precipitation event at 09.10.2006 (2.8 mm) was chosen to mark the end of this period, because it is the first rainy day which is consequently followed by days where precipitation exceeds 0mm.

With the beginning of the high flow or rainy season the modeled Q tends to underestimate the observed one and several time lags between the peaks of both graphs appear. The time lags are within one (13.10.2006 Qm 14.10.2006 Qo respectively) and two days (07.12.2006 Qm and 09.12.2006 Qo respectively). Low flows during the high flow period are underestimated, which is moderate around 21.10.2006 (2533 m^3d^{-1} difference) and as high as 18840 m^3d^{-1} (47.7%) and 17349 52.9%) m^3d^{-1} at 09.11.2006 and 17.11.2006, respectively.. The highest proportional error in the related period occurred at 12.10.2006 and is 169% (1937.9 m^3d^{-1}), the highest absolute error of Q occurred at 12.11.2006 and amounts for 38459.2 m^3d^{-1} or 57%, respectively. During the entire high flow period 38% of Qm deviate less than 20% from the observed ones, 24% have a deviation of more than 40%.

Whereas the two graphs are roughly matching each other at least visually, modeled daily runoff in period between 08.11.2006 and 18.11.2006 is obviously several magnitudes to low and the curve shape disperses significantly. The modeled peakflow at 12.11.2006 is within this period where the mean of the relative deviation accounts for 34.9%. Precipitation in that period is apparently high (290.6 mm for 11 days) with maximum peaks of 48.8 mm d^{-1}, 25 mm d^{-1}, 43.2 mm d^{-1}, 23 mm d^{-1}, 21.4 mm d^{-1}, 26 mm d^{-1}, 39.4 mm d^{-1} and 53 mm d^{-1} at 08.-10.-11.-12.-13.-14.-15.- and 18.11.2006, respectively. The smaller Qo peak at 18.11.2006 as well as the following descending sequence results from a linear regression with the Qo of BB catchment because of a gap in the input series. Also striking are the peak flows at 08.12.2006 and 09.12.2006 which are clearly not matched by the modeled graph.

The following period, starting with 21th of December 2006, is characterized by fewer precipitation events which accumulates around 21.01.2007 and 17.02.2007. The shape of the two curves matches generally better but the model tends to produce multiple peaks with sharp increase and decrease, where the observed Q shows pronounced single peaks (e.g. 17.02.2007 -19.02.2007 and 07.03.2007-10.03.2007). As one can expect, the deviation of Q for this peaks is high. Around 113% (1418 m^3d^{-1}) for the 17th and 200% (25166 m^3d^{-1}) for 07th. Contrary to the high flow period most peaks and lows are more or less too high. Low flows between days without or little precipitation is comparable to the same time span in 2006 and generally overestimated. Starting with 25.12.2006, 54% of all Qm deviates less than 20% from Qo and almost 77% less than 40%. Highest deviation with 220% (4015.4 m^3d^{-1}) occurred at the low point of 03.03.2007.

For the entire graph, only 45% of all Q have relative deviations of less than 20% and 69% deviate less than 40% from observed Q. The modeled Q of at least 5% or 28 days have deviations to the observed values above 100%.

Nash-Sutcliffe model efficiency coefficient (NS in the following) for the entire period (01.01.2006-18.05.2007) is 0.74. Viewing year 2006 only, NS becomes slightly better with 0.76.

4.1.1.2 Monthly graph

The monthly modeled and observed total runoffs for 2006, as well as the related precipitation and evaporation sums are shown in Figure 4.2. Same as apparent in Figure 4.1, the model overestimates the observed runoffs within the first half-year. This changes in September 2006 whereupon the Qm are underestimated. On monthly basis, the modeled prediction seems to match the observed Q, slightly better, whereas for individual months Qm is deviating by several magnitudes from Qo. Highest deviation is given for July 2006 where the proportional error is 62%. High deviations are also given for February (37%), October (23%) and November (26.6%), where total difference of Q is 89886.2 m^3mo^{-1}, 81275.8 m^3mo^{-1} and 252476.4 m^3mo^{-1} respectively. Best matches are in January, March and April where the proportional deviation is below 10% (9.6%, 3.6% and 6% respectively). The deviation for all the rest is consequently below 20%. An overview of the monthly results and the annual sum is given in Table 4.1

Evapotranspiration in Figure 4.2 is highest in July and August, when precipitation low. Monthly sums range between 28.2 mm in January and 89.2 mm in August. There is no transpiration reference for the modeled period and the catchment respectively. Pan evaporation measurements were done at Finca La Herradura but the series ended in May 2006 and is highly fragmentary. However, for the matching months January-May, the modeled evaporation is of the same magnitude.

The annual water balance (4.1) for B1 catchment is slightly negative, which means that the annual output is higher than the input and the storage change Δ is negative. The difference amounts to 78984.65 m^3a^{-1} which is 1.4% of the precipitation total.

$$P + Q + ET + \Delta = 0 \qquad (4.1)$$

The annual water yield, which is defined as the percentage of water input (precipitation) that leaves the catchment as runoff, for B1 is 79.5% and differs slightly from the water yield, based on observed Q (81.5%).

Table 4.1: Monthly results for B1 catchment and annual total (year 2006)

Month	Q model ($10^4 m^3 mo^{-1}$)	Q observed ($10^4 m^3 mo^{-1}$)	Difference ($10^4 m^3 mo^{-1}$)	Relative deviation (%)	Precipitation (mm mo^{-1})	Evaporation (mm mo^{-1})
Jan	45.09	41.12	3.97	9.64	339.6	28.19
Feb	33.34	24.36	8.99	36.91	202.8	31.55
Mar	46.69	45.05	1.63	3.63	384	48.24
Apr	64.12	60.41	3.71	6.15	538.8	59.19
May	46.59	40.15	6.44	16.04	243.6	58.38
June	35.37	32.56	2.81	8.64	233.2	70.00
July	12.12	7.46	4.66	62.54	104	89.33
Aug	4.15	3.50	0.65	18.54	51	102.87
Sept	3.35	4.12	0.76	18.51	106.8	68.34
Oct	26.87	34.99	8.13	23.23	371.6	58.72
Nov	69.54	94.79	25.25	26.64	557.2	69.02
Dec	52.50	60.90	8.40	13.80	341.2	66.84
	439.74	**449.42**	**9.68**	**2.15**	**3473.8**	**750.69**

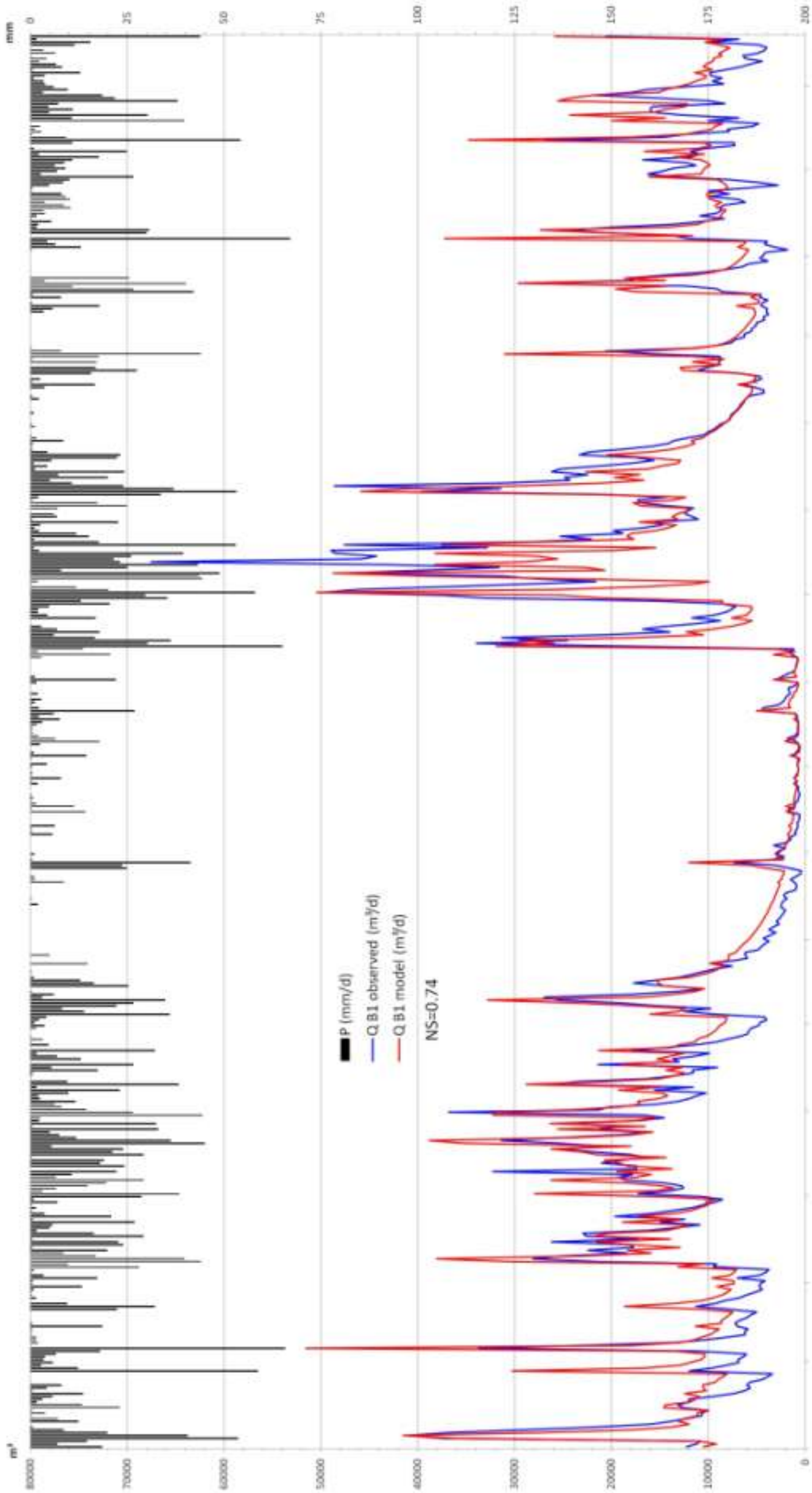

Figure 4.1: Results B1 catchment. Q is daily runoff in m^{3}d^{-1} (left axis) and P precipitation in mm d^{-1} (bulk chart with scale on right axis). NashSutcliffe model efficiency coefficient NS is 0.74.

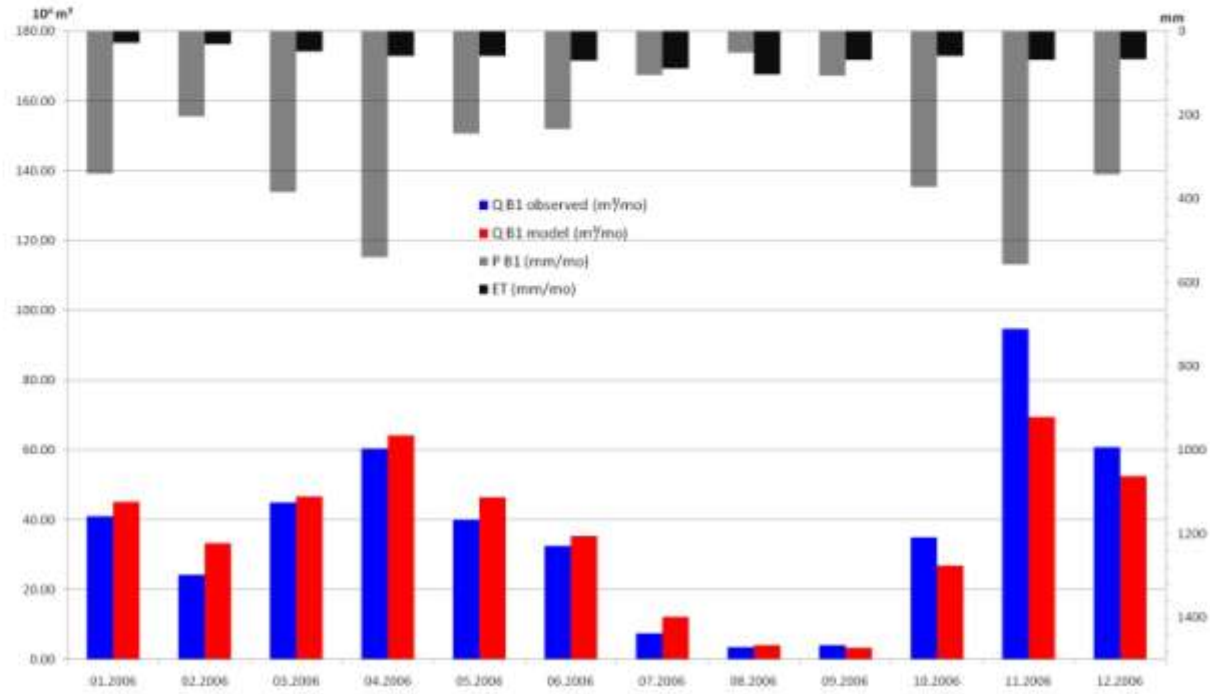

Figure 4.2: Modeled and observed monthly runoff (Q 10^4 m³), precipitation (P mm) and modeled evapotranspiration (ET mm) amounts for B1 catchment.

4.1.2 B2 catchment

4.1.2.1 Daily graph

The daily flows for B2 catchment (Figure 4.3) are generally several magnitudes more amplified in periods of high precipitation compared to B1. In opposition to that, low flows are significantly less. This is evident for the observed and the modeled graph.

In the first section, which belongs to the smaller inter annual low flow period, peakflows are more or less good matched. In January relative deviations are higher than in February for high flows as well as for low flows. The deviation of the first peak in January (05.01.2006) where Qm overestimates Qo, is 16238.4 m^3d^{-d} or 36%.The relative error is even higher for the smaller peak at 16.01.2006 (70%) and in addition to that, the model produced two smaller peaks where the observed graph shows a low. The visual performance for the rest of January as well as for February looks better and consequently proportional deviations for most Qm do not exceed 27%. Highest deviations for that sequence are given for 01.01. (32%), 02.01 (40%), 18.01. (43%), 15.01. (47%), 13.01. (57%) and 17.01.2006 (68%). Except on the 1.01.2006 this deviations are related to a the sequence where the observed graph basically shows one broad single peak and the observed one a relatively high in amplitude. In general, the relative deviations of 72% of all values during that sequence (16.01.-17.02.2007) are less than 20%, after all 40% are deviating less than 10%. Approximately 3%, which are the mentioned highest deviations, are higher than 50%.

The succeeding period is marked by collectively higher precipitation amounts which peak about the end of May (monthly precipitation totals are shown in Table 4.2). The flow rates are consequently higher whereas the observed and the modeled graph are in better agreement in March and April than in May. It should be noted that there is one extraordinary error between 06.04.-11.04.2006, where the observed graph peaks at the 09.04. and the modeled graph has a low. Precipitation amounts within the same time space are relatively small. Starting with 22.4 mm at 06.04.2006, they are dropping down to 4 mm (07.04.), 2.2 mm (08.04.), 8.4 mm (09.04.) and 0 mm (10.04.). Firstly at the 11.04.2006 precipitation exceeds 20 mm d^{-1}. The longer the rainy season lasts, the more the model seems to underestimate the high flows. Proportional deviations from March till 09.06.2006 are better than for the same period in B1. 60% of all Qm deviate less than 20% from Qo whereas 96.5% deviate less than 40%. The remaining 3.5% reflect the antithetic running graphs at the 09.04. (63.8%) and 10.04.2006 (48.5%) and the peakflow at 10.05.2006 where the modeled peak under-runs the observed one significantly (45%). 28% Qm deviate at least less than 10% from Qo. Highest total error occurred at the peak of 10.05.2006, where the model underrates the actual Q by 23150.6 m^3d^{-1}. The relatively large gaps at some low flows have a magnitude of about 30% relative deviation (e.g. 23.04.2006, total error is 4472 m^3d^{-1} where relative deviation is 28%).

The dry period from 15.06.2006-13.10.06 is characterized by extremely low flows which are consequently underrated within the first half of the dry period. This is in contrast to results for B1 catchment, where the model overrates the first half of this sequence. The decline of the modeled graph is obviously to sharp. In the same section the observed graph shows an amplitude which is not represented by the modeled results. The single peaks, which are in coincidence with relatively high precipitation events (e.g. 66 mm during 5 days between 25.07.2006 and 29.07.2006), also are not very well matched by the modeled Graph. The peak is matched fairly well but when Qo remains relatively high for a few days, Qm decreases sharply and falls back to previous state. Consequently, the relative deviation during that time is as high as 83%. To take one case in point, total deviation at 29.07.2006 is 4711.7 m^3d^{-1} (83.7%). For the rest of the dry or low flow period Qm overestimates Qo slightly in terms of total runoff but strongly considered in relative deviations. Opposite is the case for the few peakflows during that period. To give an example, the observed flow drops down to 15.2 m^3d^{-1} and 13 $m^3d^{-}1$ at the 07.09. and the 08.09.2006, respectively whereas Qm remains at around 400 m^3d^{-1} and 500 m^3d^{-1}. Thus, the relative deviations for the entire low flow sequence are high. Only 9% of all values from 15.06.2006-12.10.2006 remain below 20% of relative deviation and only 24% of Qm differ less than 40% from Qo. 63.6% or 77 daily Qm have relative deviations of more than 50% and as much as 34% differ more than 100%. Highest total differences are given for days where observed runoff drops down to almost zero but the model still produces 1000 or more m^3 a day. For 19.09.2006 observed Q was 39.33 m^3d^{-d} where the model calculated 1808 m^3d^{-1}. For the second half of September, the entire October and first half of November, almost all Qm are more than several magnitudes to high. The mean absolute deviation for the entire low flow period is as high as 1968 m^3d^{-1} at average.

The following rainy season starts with an sharp increase of Q (13.10.2006), for Qo and Qm. Qm exceeds the observed Q by 33157.3 m^3d^{-1} or 150% and under-runs the following low (22.10.2006) by 4102.8 m^3d^{-1} or 48%. The subsequent modeled peaks and lows correspond better to the observed data leading to lower relative deviations. Between 14.10.2006 and 25.12.2006 61% of all modeled Q deviate less than 20% from the observed ones. 81% have a deviation below 40% and for 7% of Qm the difference is higher than 50%. At least 26% of the values differ less than 10% from each other. The highest uncertainty is apparent between 10.11.2006 and 18.11.2006 where the model under-runs the peaks as well as the lows.

During the rest of year 2006 as well as for the residual months in 2007, the model overestimates most high peakflows but matches the descending curve sequences and the low flows fairly well. Contrary to most sequences before, the increasing as well as the decreasing curve sequences are in conformable agreement. Two multiple peaks which are generated by the model, however do not reflect the actual curve shape (17.02.2007 and 07.03.2007 where relative deviation peaks to 350% and 230% respectively). Relative deviations for the entire sequence (26.12.2006-28.05.2007) are modest compared to other parts. 65% of all values deviate less than 20% and 85% (132 days out of 155) have deviations below 40%. Only 13% of the modeled Q differ more than 50% from the observed runoffs, though highest relative errors overruns 300%. Highest total as well as relative deviation occurred at 17.02.2007 and amounts to 33453.3 m^3d^{-1} and 350% followed by 16.02.2007 with 25393 m^3d^{-1} (313%). Both dates are within the previously mentioned multiple peaks.

The relative deviation distribution for the entire graph shows 50% of Qm (254 days out of 513) in the range of 0%-20% relative deviation.72% (370 days) deviate less than 40% from observed values and 22% (111 days) have deviations of more than 50%. Highest deviations of more than 70% affect 13% of all days. As described before, these deviations are extraordinary high (thousendfold) and belong to the low flow period.

If only 2006 is considered the relative deviation distribution differs slightly. Deviations of less than 20% exist only for 45% of all days whereas the range between 20% and 40% of deviation remains constant. 68% of all modeled values in 2006 deviate less than 40% from the observed ones. 25% of the values have deviations of more than 50%. The highest absolute deviation is given for 12.11.2006 (39752.7 and 58% respectively) where the model under-runs the observed runoff. As outlined for the entire graph, the highest deviations occur in the low flow period.

Nash-Sutcliffe model efficiency coefficient for 2006 including the 2007 period is 0.77. Taking only year 2006, NS becomes somewhat better and amounts to 0.8.

4.1.2.2 Monthly Graph

Monthly results for B2 are shown in Figure 4.4 and summarized in Table 4.2.

On monthly basis the modeled predictions match the observed Q generally better, though there are still high differences between measured and modeled data. Whereas the relative error is relatively moderate for the first six months, in July the deviation becomes significant. July marks the beginning of the low flow period which in the annual graph is characterized by a significant sharper decrease of Qm compared to Qo, hence the modeled Q are under-running the observed ones. Consequently the modeled monthly discharges in July remain too low. Same is evident for August where the model did not catch a relatively large peak during the first half of the month. The turn in modeled runoff behavior, which means that the model started to overestimate the flows in the second half of August, could not compensate the accumulated minus. However, in September the overrating continues and leads to a significant to high estimate of monthly Q. With the end of the dry season and monthly precipitation amounts above 300 mm relative deviation becomes better. As shown in Table 4.2, the differenced in modeled evapotranspiration is relatively uniformly distributed throughout the year. The peak in August occurs when flows are lowest. For the grassland dominated B2 catchment the total annual evaporation as well as the monthly amounts are consequently lower than for the forest dominated B1 catchment.

Total modeled yield is 0.8 which is mostly in agreement with the observed yield of 0.87. On an annual basis the annual water balance is equated or 0, since Δ amounts to only 11.3 m^3a^{-1}.

Table 4.2: Monthly results for B2 catchment and annual total (year 2006)

Month	Q model ($10^4m^3mo^{-1}$)	Q observed ($10^4m^3mo^{-1}$)	Difference ($10^4m^3mo^{-1}$)	Relative deviation (%)	Precipitation (mm mo^{-1})	Evaporation (mm mo^{-1})
Jan	48.70	44.21	4.49	10.15	316.2	25.45
Feb	32.38	36.61	4.24	11.57	183.6	28.51
Mar	49.52	54.54	5.02	9.21	349.2	43.50
Apr	53.60	65.92	12.32	18.69	378.2	50.98
May	40.02	45.90	5.88	13.82	212.6	48.86
June	33.31	38.10	4.79	12.58	203.6	53.79
July	6.10	12.27	6.17	50.29	66	59.90
Aug	2.43	3.89	1.46	37.45	66.6	74.85
Sept	5.00	3.01	1.99	66.1	99.4	53.32
Oct	37.96	32.67	5.28	16.17	358	47.24
Nov	78.53	94.17	15.65	16.61	502	55.77
Dec	56.17	49.12	7.06	14.37	338.2	54.13
	439.74	**443.71**	**9.68**	**2.15**	**3473.8**	**596.31**

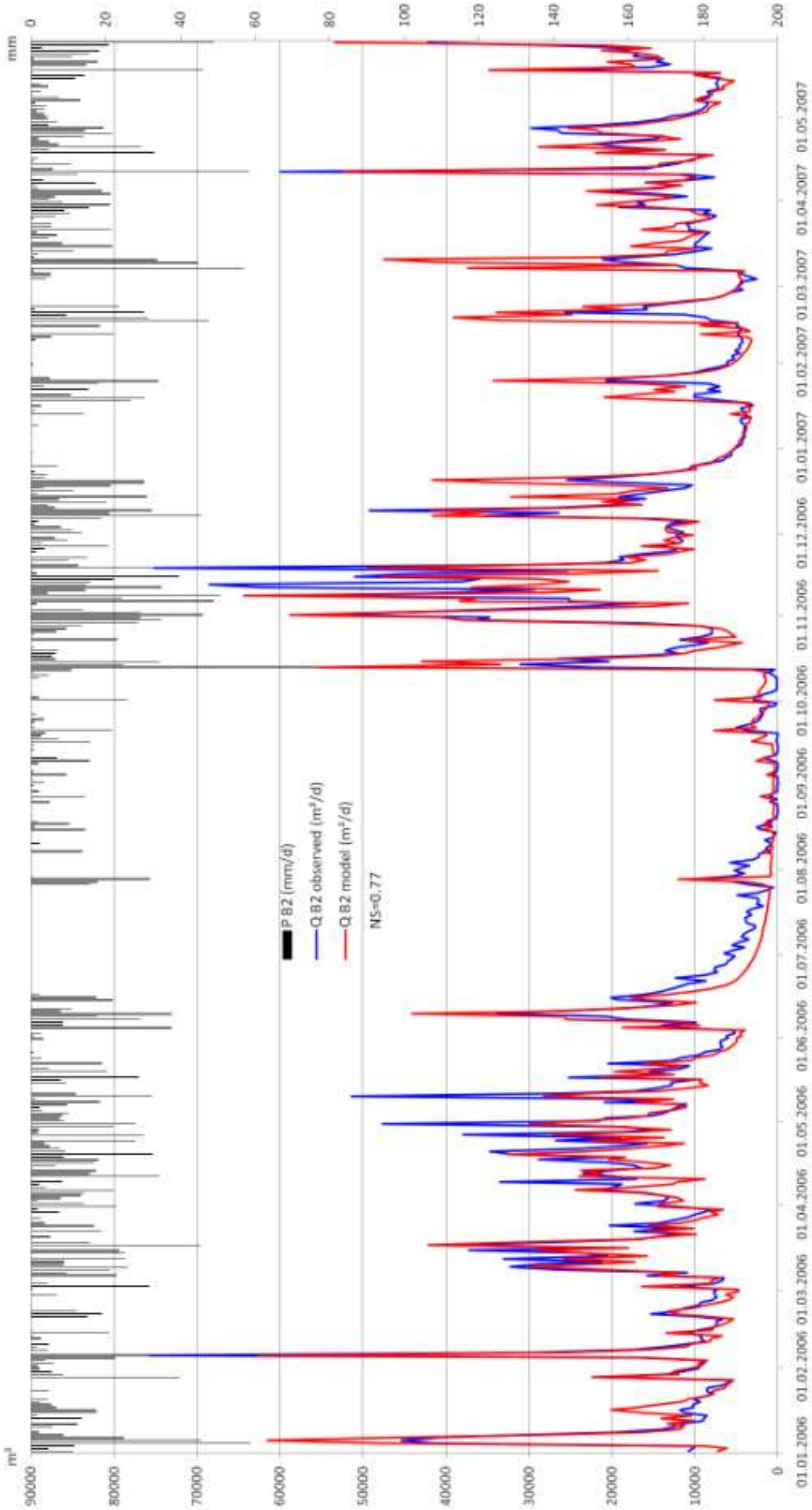

Figure 4.2: Results B2 catchment. Q is daily runoff in m^3d^{-1} (left axis) and P precipitation in mm d^{-1} (bulk chart with scale on right axis). NashSutcliffe model efficiency coefficient NS is 0.77.

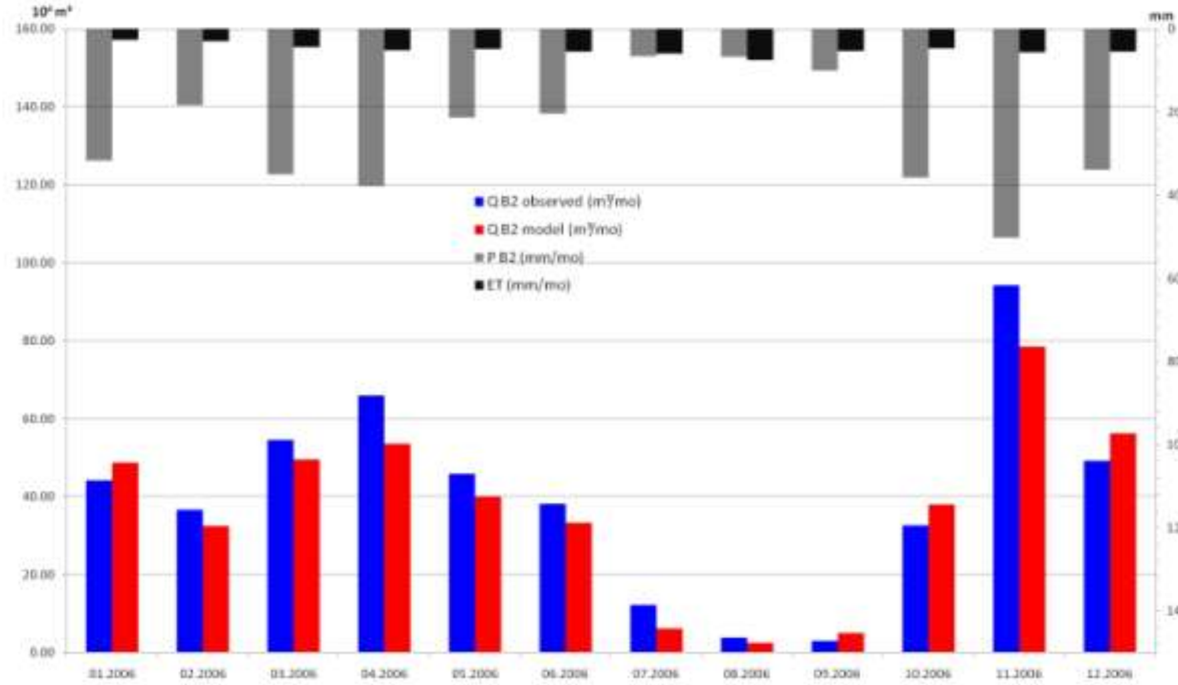

Figure 4.4: Modeled and observed monthly runoff (Q 10^4 m³), precipitation (P mm) and modeled evapotranspiration (ET mm) amounts for B2 catchment.

4.1.3 BB Catchment

4.1.3.1 Daily Graph

The daily Qm of BB catchment shows high variance in terms of low flows and peaks of lower flows during the first two months of the modeled period changing for March 2006, where the lows are better matched. From January till the end February highest deviations (>100%) occurred between 11.01.2006 and 28.01.2006 within a gap in the precipitation series (11.01.2006-12.02.2006, completed via linear regression). Highest relative deviation is given for 28.1.2006 and amounts to 1130%. At the same date, the highest absolute error of about plus 13248 m^3d^{-1} is observed. As visible on the hydrograph diagram (Figure 4.5) the modeled results tend to overrate the measured runoff basically till 09.03.2006. Relative deviations amounts up to 20% for almost 23% of all values during that period, 45% have deviations up to 40% and the relative deviations for 46% of the Qm is above 50%. 15 values differ more than 100% from the observed Q, all of them are within the mentioned gap in the precipitation series.

With the beginning of higher daily precipitation amounts (mean of 14 mm for March and April whereas mean for January and February is 8.6mm) this seems to become better. During March and April the peaks as well as the lows are better matched, though this becomes worse again towards the end of April, where the modeled graph tends to underrate peaks and lows. In May as well as in June (with ebbing precipitation amounts) the model generally tends to overrate the observed runoff again, whereas peakflows seems to be better matched than the several lows. Relative deviations for the entire rainy period (09.03.2006-26.06.2006) are as follows: 33% (37 days) have deviations of less than 20%, 44% have deviations of less than 40 and 50% deviate more than 50% from the observed values. Highest total error is observed at the 30.04.2006 where Qo is overrated to 8773 m^3d^{-d}. This is probably due to a time lag between the observed and predicted Q at this date. Highest relative errors occurred during the low flow sections of the curve within June and the end of May and reach up to 300% (01.06.2006).

The dry season, marked by the last larger precipitation event at 26.06.2006 is characterized by strongly minimized flows, although in September towards the end of the dry season BB Qo is relatively higher than observed for B2 and B1 (43 vs. 16.7 mm d^{-1} respectively 25.9 mm d^{-1}). Differences between BB and B1 are marginally (22.6 vs. 25.9 mm d^{-1}). The modeled results overestimate the observed runoff almost during the entire dry season. Firstly at the end of September the modeled runoff drops slightly below the observed level (which is obviously a reaction of a slight increase in daily precipitation). Not only the anticlimax of the observed curve is below the modeled one, also all peakflows are overestimated by the model. Consequently relative deviations during the entire low flow period (26.06.2006-12.10.2006) are high. Only 19% of all modeled Q have relative deviations of less than 20% from the observed ones. Approximately 37% deviate less than 40% and 58% have deviations of more than 50%. To conclude that picture, almost 43% have relative deviations of more than 100% which are mostly related to the beginning of the dry season in July but also to the few peaks which are produced by the model but not present on the observed data. Highest relative deviation (440%) was obtained at 10.08.2006, where the modeled graph remains relatively high after a clearly overestimated peakflow at 28.07.2006 and produces a peak of 750 m^3d^{-1} in obvious reaction to a smaller precipitation event (where the observed Q drops down to 138 m^3d^{-1} instead)

With the beginning of higher and continuous rainfall amounts with the precipitation event at 10.10.2006 or with the sharp increase of measured and modeled Q at 13.10.2006, the dry period is abruptly finished. Besides the first peaks and in relation to the generally high deviation the peaks during the following rainy period are more or less well matched. This is also valid for the lower flows during that period. Besides that it is conspicuous that time lags occur between several observed and modeled peaks.For example at 18.01.2006 where the modeled peak appears a day too early or at 13.11.2006 where the modeled peak is one day to late. At the 07^{th} and the 8^{th} of November the model produces one peak where observed data show two. For the period of intense rainfalls between 13.10.2006 and 20.12.2006 the relative error is smaller. 67% of all values have deviations of less than 20% (at least 42% deviate less than 10%). 91% (which equals 62 days) deviate less than

40%. The remaining 9% (6 days) are all related to the described time lags between the peaks (or the lows, e.g. at 17th October). Only the low at 16.10.2006, where the model underestimates the observed data significantly is therefore a true relative error above 40% (48.5% relative deviation and minus 7666.7 m^3d^{-1}).

With the beginning of the second season which is characterized by smaller precipitation amounts, the model performance drops down again apparently caused by the overestimation of smaller precipitation accumulations prior to larger events. The curve between the 20th and the 23th of January 2007 therefore produces relative errors between 63% and 111% (for 22.01.2007 and 20.01.2007, respectively). Absolute deviations range between plus 1264 m^3d^{-1} and plus 2500 m^3d^{-1} (for 22.01.2007 and 23.01.2007, respectively). Comparably results are present for the 16th and the 17th of February, where the model overestimates the observed data as well (97% and 134% relative deviation). Deviations for this period overall (21.12.2006-06.03.2007) are as follows: 75% of all Qm deviate less than 20% from Qo, 84% deviate less than 40%. 4% have deviations of more than 100% where highest relative deviation is shown at 17.02.2007 (134%). Deviations for the rest of the shown graph, and therefore a period which is characterized by modest rise in daily rainfalls is generally comparable to the period described previously. 79% of Qm have deviations lower 20%. The 4th percentile includes 98% of all remaining Qm and is so far the best matched sequence.

Deviations for the entire BB hydrograph are heavily influenced by the dry season and are as follows: 46% of Qm have relative deviations less than 20% whereas 64% deviate less than 40% from Qo. 73% have deviations below 70% and as much as 20% have relative deviations of more than 100%.

Nash-Sutcliffe model efficiency parameter for the entire period and is shown in Figure 4.5 is 0.8. Although this is the best value out of the three catchments (NS for 2006 is 0.76).

4.1.3.2 Monthly Graph

Contrary to the other catchments, where monthly predictions were generally slightly better than the daily predictions, the deviations of predicted to observed Q are higher for BB. The results (Figure 4.6) show that runoff is overrated for almost every month. Only in November the predictions are lower than the observed Q. High differences between Qm and Qo are shown for January, May, June, July and August. Moderate differences of modeled Q to observed Q are given for April, December and November which are related to higher rainfall amounts than the other months even if the precipitation difference between December and January is minimal. January precipitation was completed by a linear regression with the precipitation series for B2 catchment, which could have supported the deviation in this month. However, highest differences occurred during the dry period with highest deviation in July. Table 13 gives an overview of monthly results and annual total for BB.

Compared to the grassland dominated B2 catchment, calculated evapotranspiration is higher throughout the year which leads to a higher annual total of 632 mm.

Total modeled annual water yield is 0.81 and exceeds the observed yield significantly (total annual observed water yield is 0.68). In logical consequence of the high modeled runoffs, the water balance on annual basis is negative and Δ amounts to -15003.9 m^3a^{-1}.

Table 4.3: Monthly results for BB catchment and annual total (year 2006)

Month	Q model ($10^4 m^3 mo^{-1}$)	Q observed ($10^4 m^3 mo^{-1}$)	Difference ($10^4 m^3 mo^{-1}$)	Relative deviation (%)	Precipitation (mm mo^{-1})	Evaporation (mm mo^{-1})
Jan	19.97	12.47	7.50	60.15	359.2	28.23
Feb	10.76	8.21	2.55	31.13	159.4	27.50
Mar	18.49	16.80	1.70	10.09	376.2	44.28
Apr	23.55	22.35	1.21	5.39	473.2	53.54
May	15.17	8.18	6.99	85.44	238.2	51.09
June	11.51	6.11	5.40	88.48	214.2	58.67
July	3.21	1.46	1.76	120.29	98.8	68.56
Aug	1.89	1.00	0.89	89.29	82.4	81.92
Sept	3.31	2.66	0.65	24.35	124	56.98
Oct	13.35	12.34	1.01	8.18	345.8	48.42
Nov	26.40	30.86	4.46	14.47	497.8	57.80
Dec	16.60	16.01	0.59	3.70	290	55.01
	164.22	**138.44**	**25.78**	**18.62**	**3259.2**	**632.01**

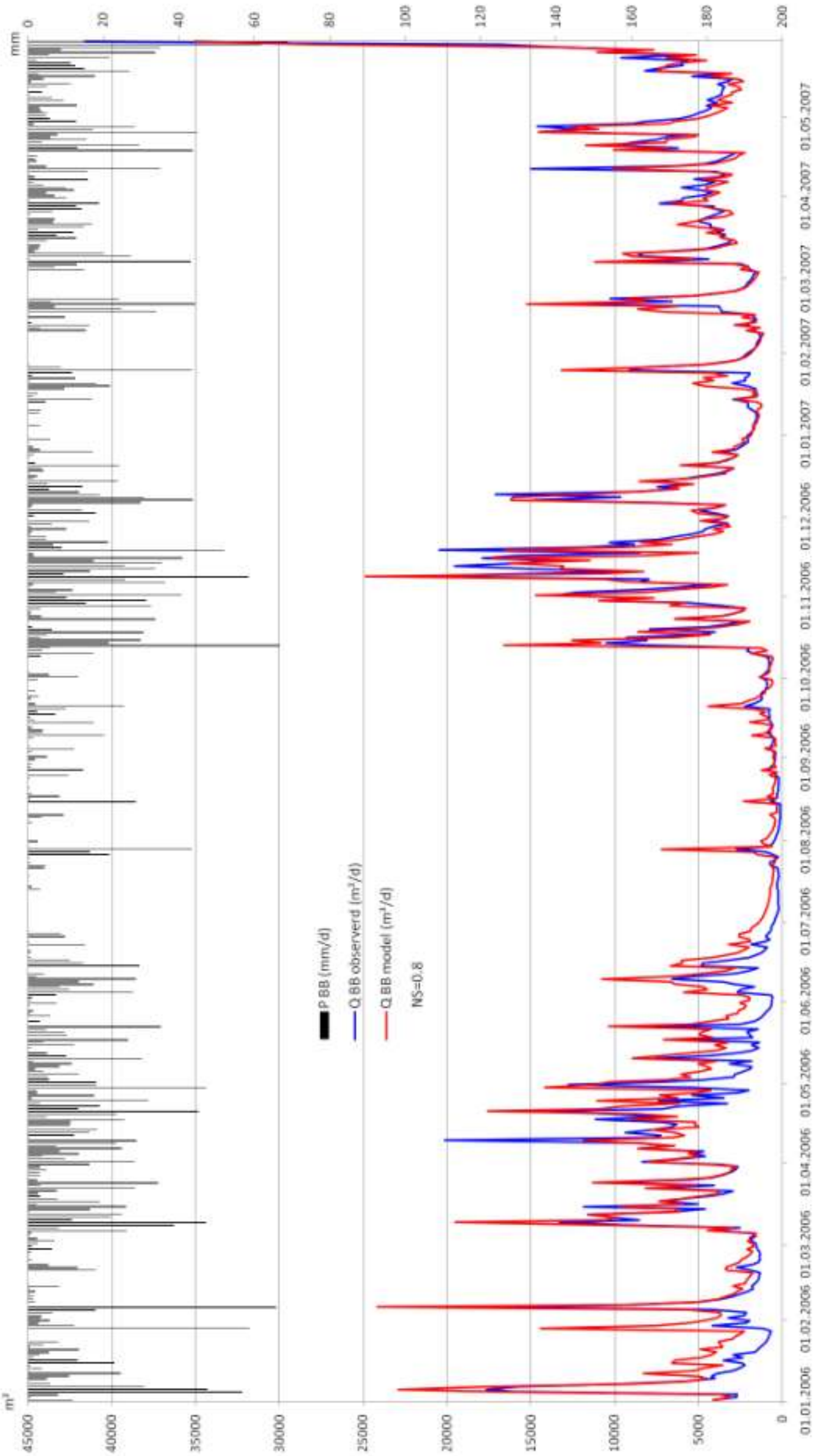

Figure 4.3: Results BB catchment. Q is daily runoff in m^3d^{-1} (left axis) and P precipitation in mm d^{-1} (bulk chart with scale on right axis). Nash-Sutcliffe model efficiency coefficient NS is 0.8.

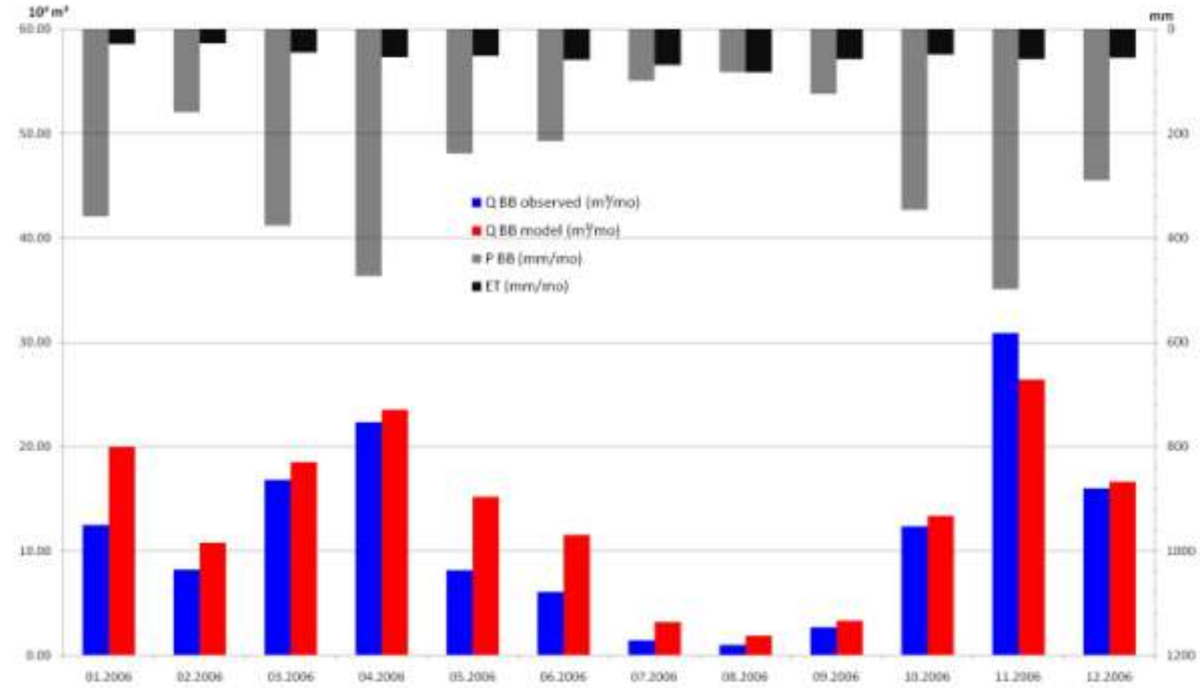

Figure 4.6: Modeled and observed monthly runoff (Q 10^4 m³), precipitation (P mm) and modeled evapotranspiration (ET mm) amounts for BB catchment.

4.1.4 Relative deviations

Relative deviations on daily basis were calculated for each catchment separately. The relative deviations of modeled versus observed streamflows are varying between the three catchments as shown in Figure 4.7.

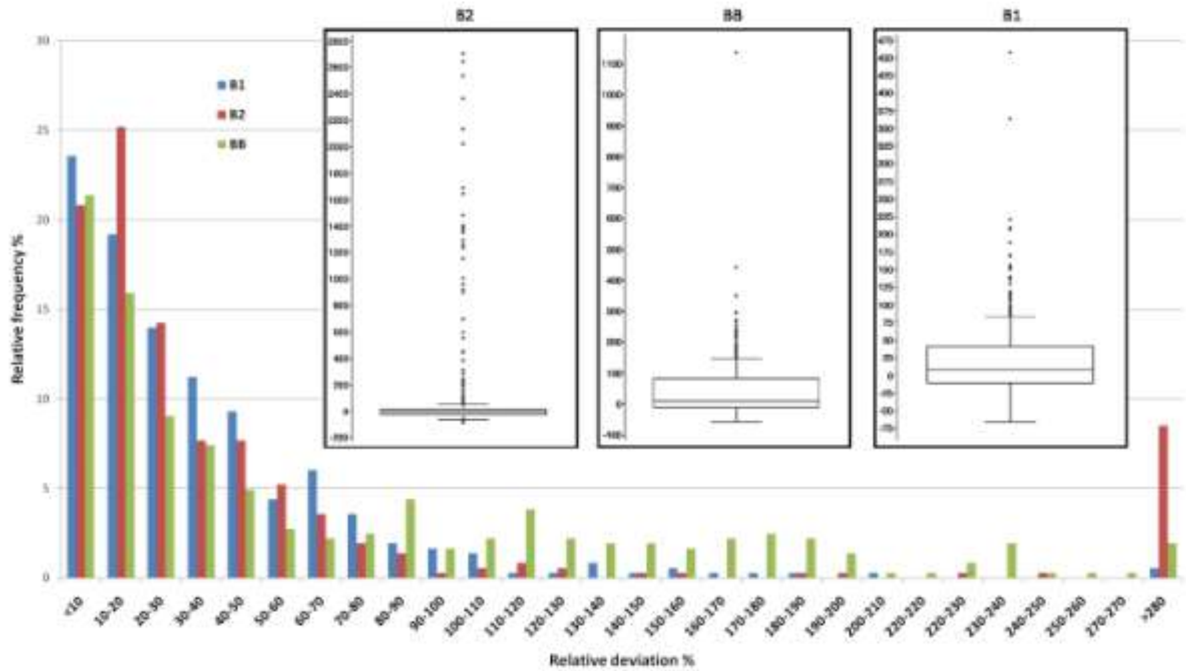

Figure 4.7: Absolute relative deviation distributions and relative deviations (box plot) for the modeled results

Due to better clarity, the values for Figure 4.7 were subdivided in 10% bins. The highest class contains all values with deviation above 280%. This is because behind 280% series of empty bins occurred which had stretched the distribution significantly. It is obvious that the highest density for all catchments is between 0 and 20%, for B1 and BB even between 0 and 10%. By contrast BB catchment Q_m shows generally the largest amounts of values with higher deviations. In turn the smallest density within the first two bins is also observed for the BB Q_m. The first and third quartiles, the median as well as the highest and lowest relative deviations are shown in Table 4.4:

Table 4.4: Quartiles, maximum and minimum of relative deviations

	B1	B2	BB
Q_1	10.2%	11.49%	11.94%
Median	24.38%	22.89%	33.7%
Q_2	45.65%	48.59%	111.77%
Lowest	0.16%	0.09%	0.09%
Highest	457.31%	4497.08%	1136.3%

Together with Figure 4.7 this draws an erratic picture of the deviations. B1 show lower relative deviations within the first quartile where B2 seems to be slightly better for the second quartile (median) but has the highest maximum deviations as well as the highest value for the third quartile. BB despite having the highest Nash-Sutcliffe model efficiency coefficient seems to have the highest relative error compared to the observed discharges. This is obvious from the graph and also from the quartiles. B2 discharges have a lower number of deviations above 100% but also the third highest distribution density for deviations above 280%.

4.2 Discharge by cover type

The B1 catchment discharge by cover type as shown in Figure 4.8 (top position) reveals clear differences between these cover types. During the dry period on relative basis (mm d^{-1}) basis the wetland discharge is obviously the highest and relatively constant. The pasture sites Q_m shows the strongest event response and has the highest peaks. Forest and cultivated forest (plantation forest) show an almost similar behavior concerning the curve shape but have a difference in magnitude. The forest runoff is generally higher than for cultivated forest although single peaks of plantation Q_m are higher. The wetland graph shows generally large peaks which then drops down below the forest Q_m level. As mentioned above, this is in contrast to the dry period between July and September. Rising quickly with ending dry period, the wetland Q_m shows the fasted response of all land use types to initial events indicating the end of the dry period.

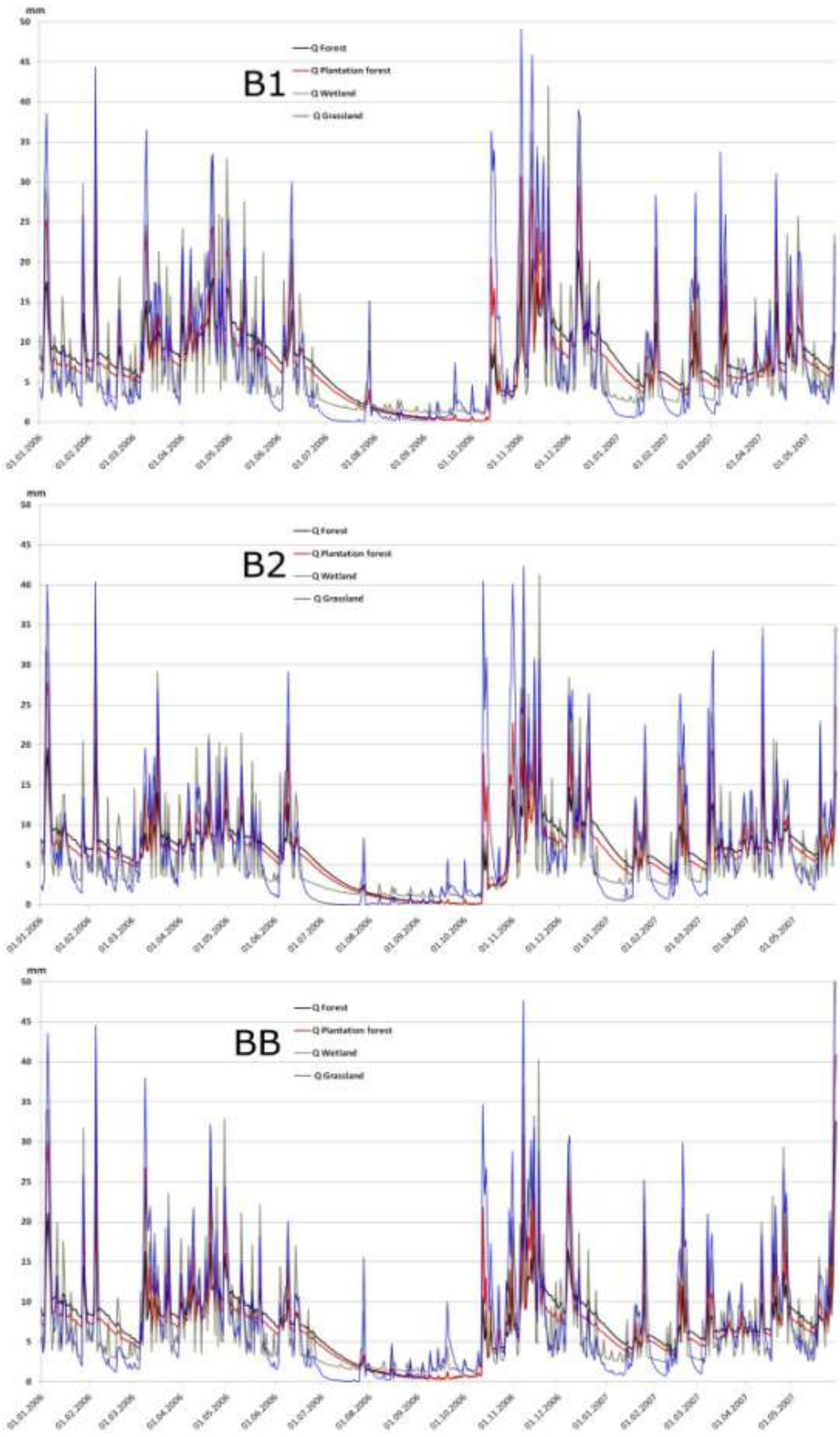

Figure 4.8: Daily modeled runoff (mm) per land use type

The graphs for the other two catchments (B2 centered position, BB at the bottom of Figure 4.8) do not draw a significant different picture. The runoff behavior of all landuse types within the remaining catchments is relatively similar to that of B1. The flows of B2 are slightly little compared to B1 as well as BB, especially obvious during the dry season. Another remarkable difference is the peak response of B2 which is smaller than for the others but wetland and grassland Q_m are slightly more affected, especially when peaks are highest. To give an example, the discharge at the 8th of September for grassland amounts to 47.6 mm (BB), 48.9 mm (B1) and 42.3 mm (B2) and for wetland to 36.9 mm(BB), 36.1 (B1) and 34.5 mm (B2). Forest discharge at the same date is 22.1 mm (BB), 20.4 mm (B1) and 19 mm (B2). Accentuating this, another example is given for the peakflows at the 9th of March 2006, where wetland discharges amount to 25 mm (BB), 24.7 mm (B1) and 14.91 mm (B2), grassland discharges to 38 mm (BB), 36.5 mm (B1) and 19.6 (B2) and forest discharges to 16.2 mm (BB), 15.1 mm (B1) and 8.9 mm (B2), respectively.

Table 4.5 shows the annual sums of modeled runoff for each cover type, where the highest differences are shown for grassland and wetland except for the comparison of B2 and BB where the highest difference is between the forests Q_m.

Table 4.5: Annual sums of Q per land use type

	B1 Q (mm)	**B2 Q (mm)**	**BB Q (mm)**
Grassland	2919.27	2538.96	2711.59
Wetland	2773.92	2384.88	2586
Forest	2693.78	2320.58	2528.42
Plantation forest	2701.59	2339.58	2525.87

The modeled wetlands have the highest runoff during the driest period and show a relatively constant discharge in the months where runoff of other land cover types drops down significantly. During the rest of the year the modeled grassland Q have almost completely the highest monthly values, which is the result of the continuous large daily peaks as shown in Figure 4.8. Forest and plantation forest, despite for January and February 2006/2007 and December 2007 show generally lower relative runoffs. January, February and December is within the *small* dry period which is characterized by relatively moderate precipitation and where the wetlands and grasslands of the daily graph showing single peaks but all lowflows are below them of forest. Figure 4.9 gives an overview of the monthly modeled runoffs in mm.

To complete the picture, Figure 4.10 shows the modeled monthly discharges for each land cover type related to its portion of total catchment area. In the dryer months July, August and September the discharge for all land cover types drops down. Taking wetland discharge as example, in BB which has the largest portion of wetlands has the highest discharge from this cover type within this period (BB

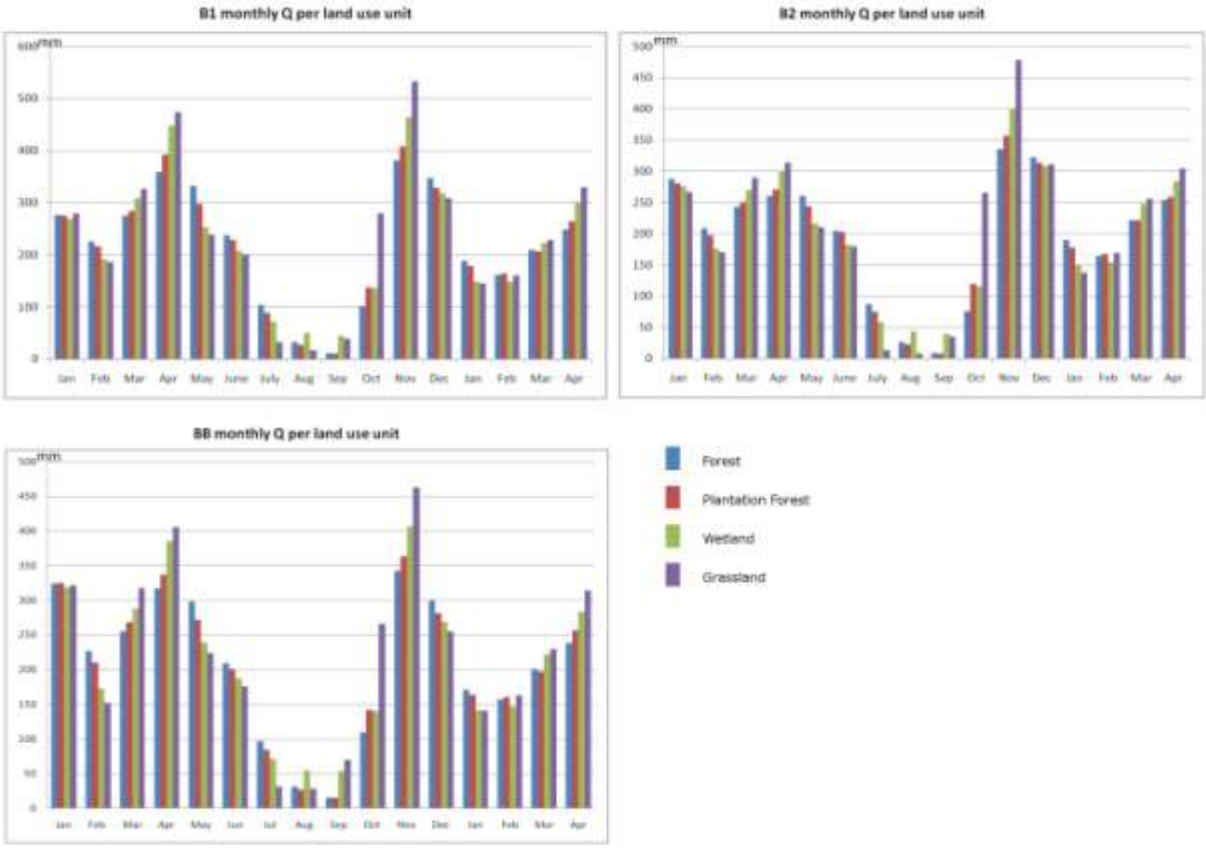

Figure 4.9: Monthly Q_m (mm) related to land cover type

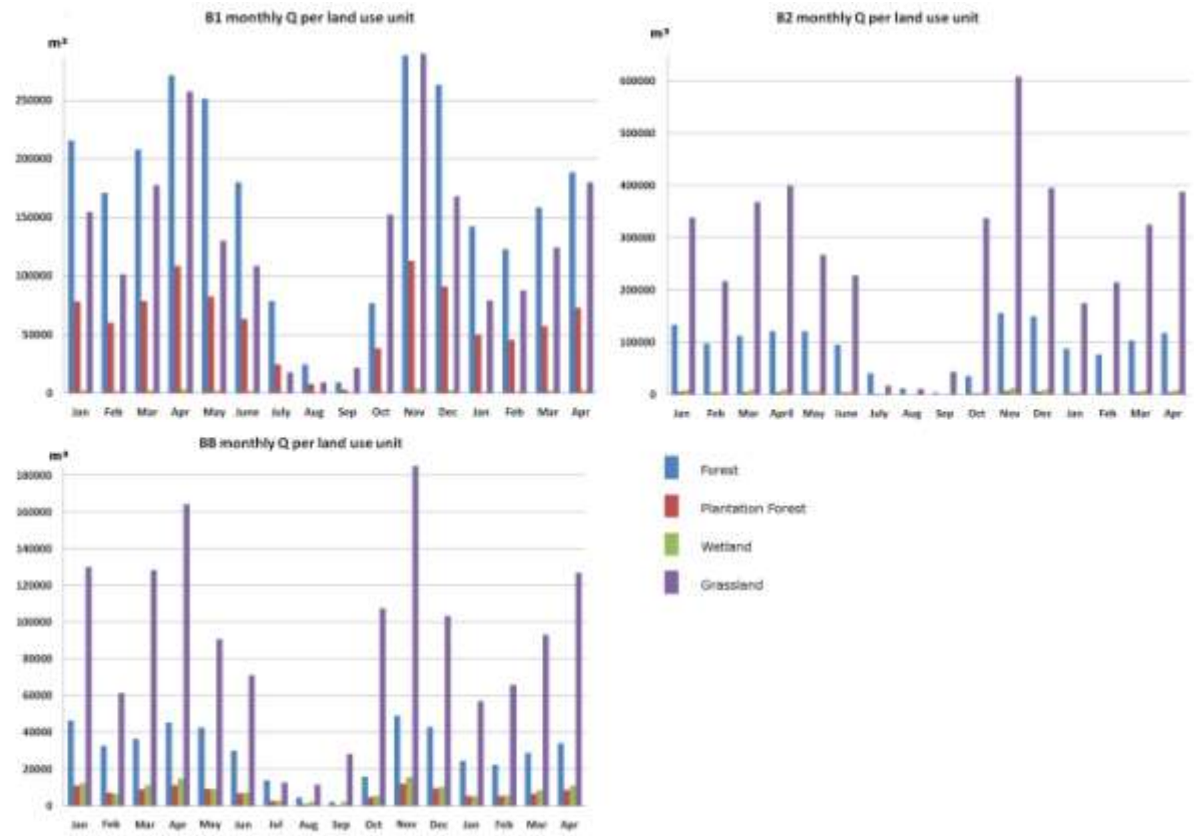

Figure 4.10: Monthly Q_m (m^3) related to land cover proportion

has 6905.2 m³ whereas B2 has 4485.2 m³ and B1 has 1326.4 m³). On annual basis the BB wetland discharge amounts to $142.5*10^4$m³, B1 to $29.4*10^4$m³ and B2 to $109*10^4$m³ respectively. Thus the relative gap between the wetland-discharge related to each catchment is slightly higher on annual basis than for the dry period.

4.3 Model Sensitivity

The model sensitivity was tested for all parameters except for parameters which were turned off (not used parameters). It is considered that a sensitivity analysis would determine how changes in value of parameters affect the model. Therefore new model runs were performed with the varied parameter and the Nash-Sutcliffe model efficiency coefficient was calculated. The sensitivity analysis includes B1 and BB catchment and for these separated tests for each land uses type were done separately. All in all ca. 280 parameters were tested like this. Parameter variation within the sensitivity analysis denotes a 10% increase as well as a 10% decrease of each parameter separately. Varying a parameter value to 10% means a variation within its physical range (or common range in the case the parameters definition is fuzzy and not derived from calculations) and not of its actual selected value. As an instance, MAXLAI (leaf area index at its seasonal maximum) for the forest sites was set to 5 during the modeling. Considering a MAXLAI of 3 for some crops and of 4 for shrubs the lower limit for deciduous and evergreen woody plants was set to 3.5. The upper limit of 7 was derived from literature (e.g. Roberts et al., 2005). In order to this, MAXLAI was varied to 4.65 and 5.35 which is a variation to 10% of the defined range. Variation of the stomata conductance was done within the calculated lower limit (as discussed in chapter 3.1.1.3.1) and the maximum value for some plant species (2 cm s^{-1}) as given by Federer, (2002). Some exceptions were made for parameters which do not have a common or physical range. For these parameters the 10% value was calculated from its actual value. As an instance, the thickness of each soil layer was varied to 10% of the total soil depth (e.g. 1500 mm for forest soils) which is a variation to 350 and 650 mm for each of the three soil layers. Same was done for parameters like soil water content at saturation (THSAT, 0.61 cm³ cm^{-3}) which denotes a variation of 0.061 for each forest soil layer. A few parameters are more or less *intuitive* parameters (Federer, 2002) for these (e.g. QFPAR, a flow parameter which determines the fraction between field capacity and saturation that becomes a quick flow component), the upper and lower theoretical limit as given by Federer (2002) was used to define the 10% intervals.

To evaluate the model sensitivity, the absolute relative deviations of the new Nash-Sutcliffe coefficients to the Nash-Sutcliffe coefficient of the model period were calculated. Absolute relative deviations are illustrated in Figure 4.11, which shows the parameter classes on the x-axis and

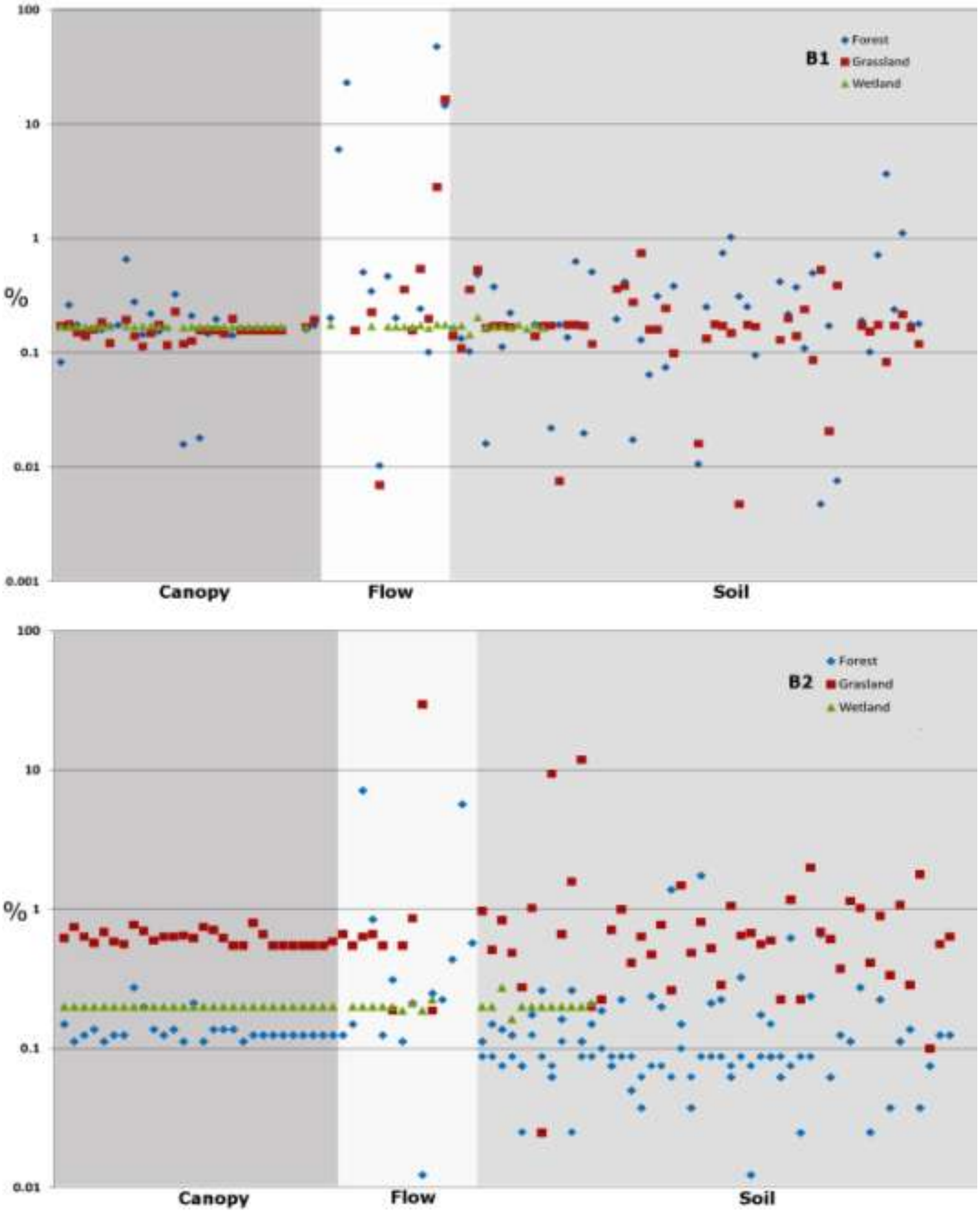

Figure 4.11: Sensitivity of the model on runoff to changes of single parameters

the relative deviation (%) on the y-axis. Due to better distinction the y-axis is of logarithmic scale, since most of the deviations are relatively small and obviously in the range of 0.1-1%. Note, the x-axis is besides the arrangement of parameter classes without special reference.

Wetland parameters do obviously have the lowest scattering, no matter if canopy, flow or soil related. This is valid for both catchments. Highest scattering is shown for forest parameters, which include the values for plantation forests. Generally for all land cover types, the scattering of Nash-Sutcliffe deviations is highest for soil parameters whereas the deviations mostly are within 0.01 and

1%. Some dots in the flow parameters section showing the highest sensitivity of all sections, both for grassland and forest and also for both catchments.

For B1 (top position of Figure 4.11), highest sensitivities are given for QFPAR (+10%) QFPAR (-10%) and GSC (-10%) which amount to 47.6%, 14.6% and 23% respectively (in the following parameters will have a superscript + or – instead of referring to 10%). Both of them are related to forest flow parameters. The red dot above the 10% line, indicating a grassland flow parameter reflects as well $QFPAR^-$ and amounts to 16.3% absolute relative deviation. Furthermore, relatively high deviations (above 1%) are shown for GSC^+-forest which amounts to 6%, $QFPAR^-$-grassland (2.8%) and the forest soil parameters $THETAF^+$ in soil layer 3 (1.02%), $THSAT^-$ in soil layer 2 (3.6%) and $THSAT^-$ in soil layer 3 (1.1%). Other relatively sensitive parameters are the layer thickness of soil layer 3 for grassland as well as $THSAT^-$ and $THETAF^+$ of layer 2 of forest soil parameters. Over all, highest sensitivities are given for forest site related parameters.

For B2 (bottom position of Figure 4.11) the derived picture is slightly different where highest overall sensitivities are shown for grassland related parameters. In contrast to B1 the highest absolute relative deviation is given for $QFPAR^-$ (29.7%) followed by $THSAT^-$ for soil layer 1 (11.9%) and $THETAF^+$ (9.4%) within the same layer. Furthermore, deviations between 1-2% are given for varied layer thickness of all 4 soil layer, where the negative variations produced slightly higher deviations. $THETAF^{+-}$ of layer 3 and 4 as well as BEXP are within the same range.

Worth mentioning are the deviations for GSC^- (7.1%) and QFPAR (5.9%), where both referring to forest flow. Relatively high sensitivities within the forest related parameters are also shown for $THSAT^-$ and $THETAF^+$ with 1.7% and 1.3% respectively.

Low sensitivities are obviously given for canopy parameters, both for the two catchments as well as for the different cover types. Furthermore, the modeled runoffs seem to be relatively insensitive to variations of wetland related parameters as well as for most other parameters which were not discussed here in particular.

5 Discussion

5.1 Model performance

The performance of daily modeled discharges for all of the three catchments reveals a mixed impression. The Nash-Sutcliffe model efficiency coefficient (NS) is in a range that has been described satisfactory by other authors, especially in relation to land use-runoff modeling. An NS of 0.63 is given by Weber et al. (2001), and considered to be acceptable. Fohrer et al. (2001), revealed NS of the same magnitude for small forested watersheds in Germany. With respect to land use change impacts on runoff in a humid tropical watershed, Combalicer et al. (2010), reported efficiencies of 0.58 and 0.74 for the modeled results on daily basis. Within the present approach NS is between 0.74 (B1) and 0.8 (BB) and even slightly better considering only the results for 2006 instead of the whole period 01.01.2006-28.05.2007. However, some peakflows are obviously overestimated where others are below the observed. Especially in periods where continuous rainfalls at preceding days probably generated high antecedent soil moisture the model tends to underestimate the peakflows. This implies that the portion of quick flow due to saturation excess or saturated soils is underestimated or was not correctly realized. Affecting in particular B1, it suggests probably the activation of some preferential flow paths and in turn a misinterpreting of these processes by the model. Another reason could be related to the previous dry season which was underestimated by the model towards the end. Lower modeled low flows with the beginning of the rainy season indicate relative low soil moistures. Since B1 is the forest dominated watershed, the water consumed by plants during the previous period was probably overestimated. During the dryer months July-September the total modeled evapotranspiration of the forest sites in B1 amount to 270.5 mm whereas the grassland sites in B2 reveal an evapotranspiration amount of 160.6 mm for the same period. Since B1 is a forest dominated catchment (more than 60% of its total area is covered by forest) and B2 is mostly characterized by open pastures (69% grassland surfaces) the total difference per area is obviously high. Supporting this argumentation, the B1 catchment runoff towards the end of the dry period is underestimated and is continued with beginning rainy season. Significant underrating of peaks and low flows occur for the first peaks within the rainy season.

The opposite is the case for B2 catchment, where low flows are overrated in the second half of the dry period. This is continued by overrated peaks and low flows with beginning of continued rainfalls. Following the previous argumentation, evapotranspiration as calculated by the model are possibly to low for the grassland sites within the dry period.

However, the forest areas were the only land use types where the Brook90 first order groundwater routine was applied. This was done since it was the only practicable way to attenuate dramatically high peakflows combined with significantly underestimated low flows in respect of the entire modeled period. Since the actual information about soil and geology was very limited this implies a high uncertainty and probably limits soil evaporation due to over-estimated amounts of water within the sub routine.

The results for BB are drawing a slightly different picture. Besides the fact that catchment discharges at beginning dry season are consequently several magnitudes too high, the fit towards ending period is generally better and is continued within the incipient rainy period.

However, the mentioned underrating of several peakflows during November 2006 (12.-18.11.2006) is apparent for all catchments whereas different in magnitude (Figure 5.1). The highest magnitude is observed for B1 catchment where the precipitation events during these days were characterized by a relatively high total amounts. Within the 12th of November total rainfall was 23 mm, distributed over 9 hours. In comparison, the total of 13th was 21.4 mm within 8 hours and for 14th of November 26 mm distributed over 10 hours. The total rainfall for 15th of November was 39.4 mm and distributed over less than 6 hours. Although the intensities seem to be moderate in daily resolution, on hourly basis some of them are much higher. Intensities for the 12th and 15th of November reached 10.4 and 13.6 mm per hour at maximum (during ca.1.5. hours each). At 18th of November 53 mm were recorded during 7 hours with a maximum intensity of 25 mm h^{-1} lasting for 2 hours. The remaining days have significantly lower intensities, whereas the amounts are still above 20 mm d^{-1}. This suggest that the model was overrating infiltration capacities which is probably related to underestimated saturation excess or Hortonian overland flow and returns it to the probably low soil water content estimation of the model which was mentioned before and assumed to be still a result of the dry season.

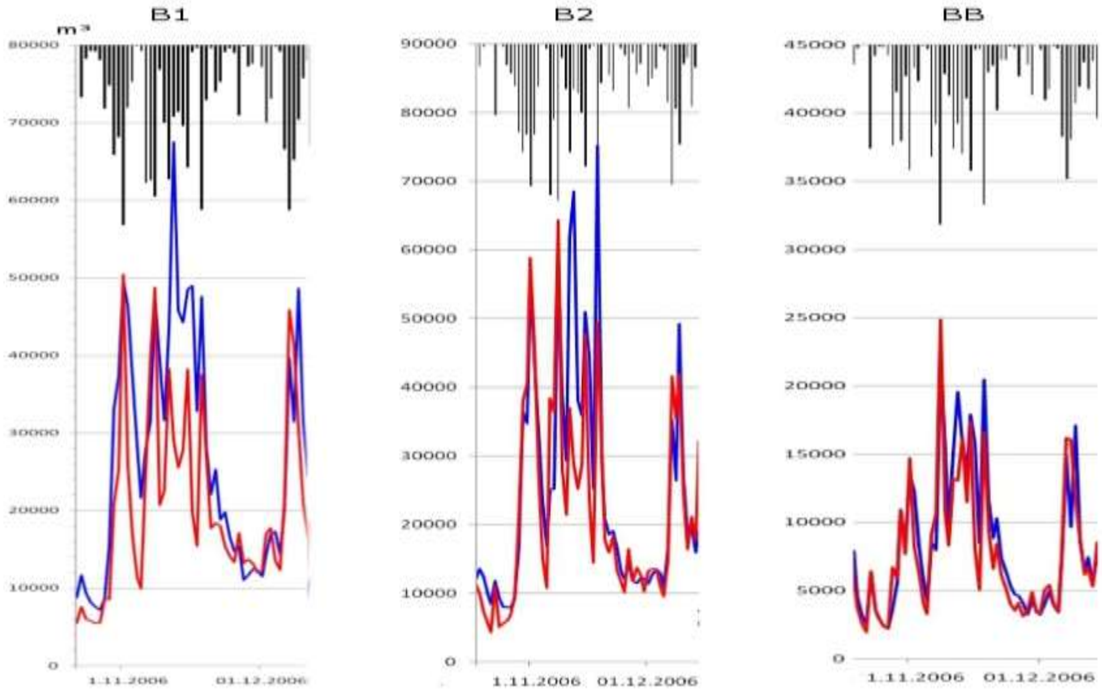

Figure 5.1: Mismatching modeled peak flows (red) and observed peak flows (blue)

Comparing the mismatching peaks between B1 and B2, the different distribution is mainly a result of different distributed event intensities. The initial events at 12th and 13th November are generally smaller (14.8 mm and 16 mm during 7 hours each) and have smaller intensities (5.8 mm h^{-1} at maximum during a one hour interval). Same is given for 24th November where the B2 precipitation record amounts to 22.2 mm during 11 hours. This changes with 15th November, where the total amount of 39.6 mm is still at the same magnitude as given for B1 but the maximum intensity of 15.6 mm during a one hour interval is remarkably higher. Where at 16th and 17th of November total daily rainfall is almost zero, the event at 18.11.2006 amounts to 55.2 mm d^{-1} where 52 mm where recorded during two hours which indicates an event of high intensity.

BB the catchment with the highest portion of wetlands shows better matched peaks, for the mentioned events as well as for the entire modeled period. Indicating that the event response of BB catchment is generally better covered by the model, the total rainfall amounts as well as the intensities for the period between 12th and 18th November are of the same magnitude as described for B2. The rainfall amount of 12th is 25.6 mm with a maximum intensity of 12 mm h^{-1}, 35 mm were recorded for 13th of November with a relatively high maximum intensity of 18.4 mm h^{-1} and precipitation of 14th of November was 41 mm in total and a relatively moderate intensity of 30 mm uniformly distributed over three hours. Same as for the other two catchments, the record at 18th of November showed the highest total (52 mm) as well as the highest intensity (23.7 mm h^{-1} lasting for almost 3 hours).

Due to the fact that underestimated modeled peaks generally belong to the rainy seasons the conclusions which was made above can be extended to the entire modeled period. Some exceptions are given for the small rainy period in B1 where the high flow at 20.40.2006 was overestimated by 62% and some smaller peaks of prevailing days deviating to the same magnitude. A general problem of the initial conditions might at least partially explain this large gap as well as the general worse model performance for all catchments during the first two months. Federer (2002) recommends a lead time of several years to account for the antecedent moisture conditions in the three catchments. In respect to this the precipitation data for 2004 and 2005 were used to set the initial conditions but due to the lack of other meteorological data these series where combined with conditions of 2006. However, a more general discussion of this problematic can be found in following sections.

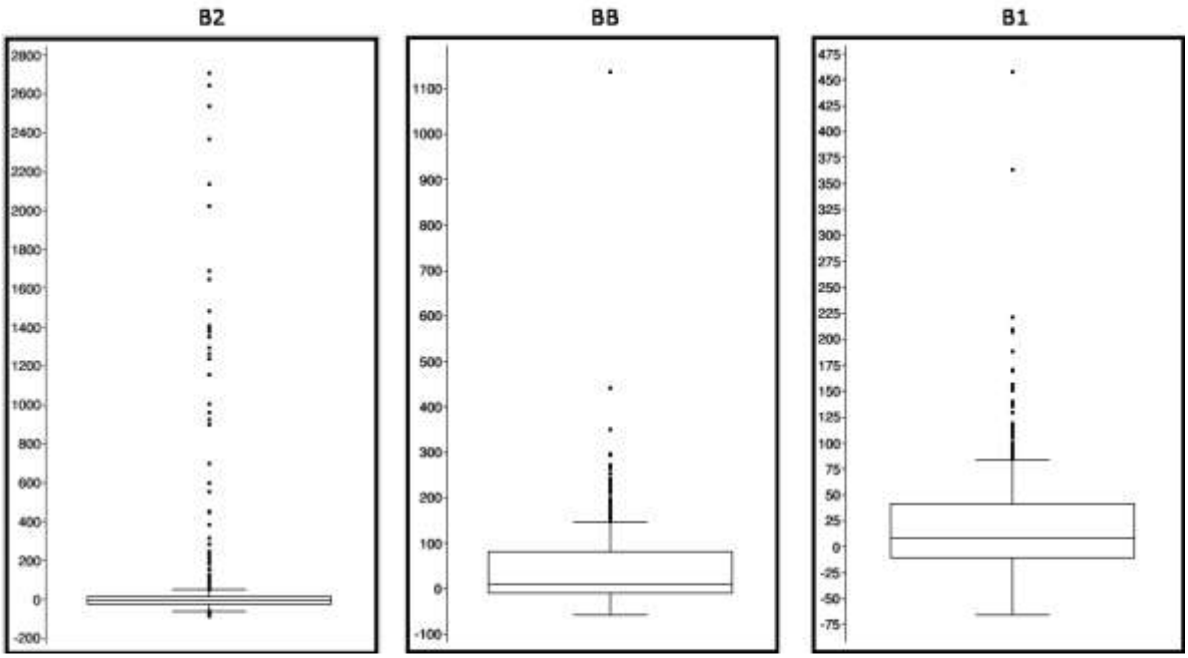

Figure 5.2: Relative deviations of the model results

The relative deviations are shown in a box plot in Figure 5.2. Even though the first and third quartiles show relative deviations of <100% an >-100%, a clear trend for high positive relative deviations can be found, especially for B2. Most of these are related to the low flow season where the model generally overestimates the observed discharges. Considering the deviations above the median shown for B1 this becomes remarkably. The B1 deviations are mostly related to the second half of the low flow season, where the highest negative deviations are related to the first half of the low flow season (opposite is the case for B2). This is probably a result of wrong land cover portion estimation. B1 has a relatively high portion of plantation or secondary forest (17%) which is at least partially without direct connection to the streams and/or has a relatively large portion of forest without direct connection in general. The forest areas of B2 are almost uniformly riparian forest and are therefore with more or less direct stream channel connection. Taking this into account and with consideration to the low hydraulic conductivities which are reported for the entire study site soils, the assumption given by Roa-García (2009), that the forests areas are generally attenuating storm flows but contribute to low flows during the dry season might be partially wrong. The main differences between the study sites discharge behaviors were assumed to be describable by the differences in grassland and forest respectively. In reference to the differing low flow behaviors of B1 and B2 it would be conceivable that the parts of the forest areas do not significantly contribute to low flows from which follows that the water is stored locally and mostly used by plants. The possibility that it contributes to overland flow is not likely since forests generally tend to attenuate storm peaks (L. A. Bruijnzeel, 1990, Bruijnzeel and Proctor, 1995) and the observed peaks do not imply such behavior. However, taking this into account the implication for B2 catchment is that it is more the riparian forest than the total forest area which is relevant low flow contributions. Despite the fact that the general comprehension of riparian forest impacts on low flow, Chestnut et al. (2000) reported base flow contributions by riparian forests the dry season within a Puerto Rican watershed in the Luquillo Mountains. Flow pathways below the riparian root zone were contributing significant amounts of flow under base flow conditions .

Nevertheless, these considerations would only partially explain the irregularities between the observed and modeled flows and are beyond the horizon of this approach. What is clear, is that the heterogeneity of the study sites land cover is much higher than assumed in the model and is at least partially mismatched by the modeled runoffs.

Despite the partially high gaps between daily observed and modeled stream flow, the model predictions seem to be at least slightly better on monthly basis. Absolute relative deviations of monthly discharge sums are generally below 20% for B2 catchment except during the dry period where highest deviation are given for September 2006 and amount to 66%. The monthly characteristics of B1 are general comparable whereas high deviations (37%) are also present for February 2006. Since February belongs to the *small* dry season and the model is overrating the observed discharge it follows the observation of the daily results, which are showing that most low flows during dry periods are overestimated in B1. The worst result on monthly basis is shown for BB catchment where except for November, all flows were overestimated but especially low flows. Nevertheless, the total monthly errors during the dry and small dry season are moderate and are of the same magnitude as for other comparable studies. Combalicer et al. (2010) stated a annual error of average streamflow of 1%, whereas the dry season flow had an relative error of 98% and the wet season relative deviation was -8.5%. Weber et al. (2001) revealed deviations of 10% for a one year period modeled with SWAT and 7% for e period of three years. The relative error for annual average flow within this study amounts to -2.2% for B1, 8% for BB and is as low as 0.9% for B2.

5.2 Model sensitivity

The parameterization of a model is per definition somewhat subjective. This is caused by a range of assumptions which were already done previous to parameterization while assessing the study site, climatic influences and so on. Subjectivity is likely to influence the process of parameter estimation, especially in cases where these parameters were not measured or observed. The model sensitivity analysis was done to derive an impartial picture of the model behavior to particular parameters and parameter classes. Therefore single parameters were varied to +10% and -10% of their physical range, or for parameters which literally do not have a physical range (e.g. thickness of soil layers) as well as for parameters where the physical range was unknown (e.g. soil texture related parameters) the parameter was varied to +10% and -10% of itself. Finally, for some parameters it was not possible to apply the -10% variation since them are not allowed to be less than 0 or its negative variation had force them in physically incorrect ranges (as an instance, THSAT which is the water content at saturation cannot be forced to be less than water content at field capacity THETAF). In such cases the next smallest value was used as lower limit instead of the -10% interval.

The results of the sensitivity analysis show relative low sensitivities to most parameters within the applied interval. Despite that, parameters which showed relatively high sensitivities are generally related to flow parameterization. QFPAR showed high sensitivities that resulted in NS variations up to 47% by varying QFPAR to +10% within the forest setup for B1. A NS deviation of 14% was observed for the negative variation within the same setup. The sensitivity of the model to this parameter is underlined by the fact that its variation for the grassland setup within B1 amounted to 16% for the negative variation and to at least 2% for the positive variation. This is remarkable because as a result of the model structure, the model should generally be more insensitive to grassland related parameters within the forest dominated B1 watershed than parameters related to the forest setup. This is also valid for the opposite case where QFPAR likewise indicates the highest sensitivities both, for the grassland as well as for the forest setup and caused a deviating NS of 29.7% and 5.7% respectively. The forest setup related flow parameter GSC showed sensitivities of the same magnitude though the deviations were slightly lower (23% of NS deviation for B1 and 6.2% for B2). Furthermore local sensitivities of more than 1% were observed for single soil parameters such as THSAT and THETAF. As an instance, the negative variation of THSAT for grassland soil layer 1 within B2 gained a sensitivity of 11%.

It should be noted that QFPAR is a subjective parameter determines the fraction of water between field capacity and saturation that becomes overland or bypass flow. A QFPAR of 0 would force al water above field capacity to become quick flow and it is not upwards limited. For the sensitivity analysis QFPAR was varied to 0.48 which is 10% of its common range given by Federer (2002), but it is even double of its value used in this study. This indicates that besides the sensitivity analysis shows sensitivities or insensitivities of the model due to parameter variations, for parameters which are subjective per definition, the impartiality while defining the variation interval is somewhat affected.

However, the canopy parameters did obviously show the smallest sensitivities for all land cover setups as well as for both catchments. Another obviousness of the sensitivity analysis is the relative insensitivity of wetland related parameters. Both are mostly an effect of the model structure as used in this study. Since the total modeled runoff is the result of the partial runoff derived for single land cover types, the model sensitivity for the wetland related parameter changes is relatively small. The same is valid for forest area related parameter changes within B2 catchment and grassland related changes within B1. The insensitivity of canopy parameters probably indicate that the 10% range is quite small but could be also related to the high annual precipitation wherefore transpiration is not significantly limited, even through relatively dry periods.

Finally it should be noted, that the model structure makes it hard to apply systematic parameter changes as for a sensitivity analysis. Overall the model in the way it was used her, includes more than 30 different parameters, depending on the number of soil layers even more. This causes that for the application of both criteria within one land cover type setup (+10% and -10%) up to 100 model runs had to be performed. All in all, for one catchment up to 300 parameters had to be varied manually since the model does not have an option to automate this procedure. Besides some other reasons which go along with a general dubiety of the wetland modeling and will be discussed later, this was the reason why the sensitivity analysis was limited to B1 and B2 catchment.

5.3 Parameter estimation and uncertainties

A general problematic of the model application was caused by short input data time series. In comparable studies the presence of a longer times series allowed the definition of a calibration and a validation period . In the present study the precipitation series were limited to two complete years and half of 2004 and 2007. Most meteorologic series were limited to 2007 and in almost all series the presence of irregularities required several corrections. Since the series were limited in time, the possibility of statistical approaches was limited too. Additionally some minor gaps within the precipitation series where found by chance, suggesting the possibility of further irregularities which probably were not found. Nandakumar et al. (1997) stated that a bias of 10% in rainfall may cause a bias up to 35% in predicted runoff. Furthermore, the application of calibration and validation within the same period is likely to lead to subjectivity.

As mentioned above, the model structure as used in this approach leads to an overall parameter emergence of more than 100 parameters. Where Brook90 in general accounts to a third of these parameters, its grouping to consider different land use types led to trebling of input parameters. This large number of parameters is still not an upper limit and can be easily increased by considering more land use types. Even if some parameters, such as canopy parameters may stay the same and only soil setup is varying the amount of needed parameters would increase significantly.

Generally, parameter selection should be done based on knowledge of its concrete value within the study site, if this is not possible for single cases could be done by deriving it on basis of known dependencies to other parameters that are available . As an instance, it is common to derive soil related values such as water content and hydraulic conductivity at several states of saturation by applying pedo-transfer functions such as given by Clapp et al. (1978), Brooks et al. (1964) or Hodnett, et al. , where the latter is related to tropical soils. For the concrete example the application of the transfer functions requires that soil texture, sand fraction, clay fraction etc. must be known or at least reasonably estimated. None of this information was available for the study site.

5.3.1 Soil parameterization

In the example of soil related values another problematic is caused by Brook90. Brook90 usually requires most soil parameters defined at field capacity, where the definition of field capacity is generally crucial since there are various definitions (e.g. in Nachabe (1998), and Colman (1944)) which makes it even more problematic to define these values. The fact that Federer (2002), defined his very own definition of field capacity, which may or may not improve common definitions, it makes data acquisition additionally complicated. If soil related data for the study site are already available it is unlikely that the measurements followed the definition used in Brook90. However, parameters such as hydraulic conductivity which is used to calculate matric flow are allowed to be used at any other state deviating from field capacity but would lead to incorrectness by calculating flow behaviors above saturation (Federer, 2002). At the study site, soils are generally characterized by high soil water content and due to the small release coefficient it is likely that most precipitation inputs are producing conditions above saturation, especially for wetland related soils but as well for grassland sites. The parameters given by Roa-García were related to saturated conditions, wherefore the exponent of the Brooks and Corey relationship (BEXP) was derived through a regression of the log -Ψ-log-Θ-relationship which may lead to incorrectness. In absence of data, Federer (2002) suggests to set hydraulic conductivity at field capacity for forest soils to 5 mm d^{-1} which gained good results throughout a large range of soils. Due to the high organic matter content at the study site, for forest soils this value was slightly minimized what in fact was done subjectively. For soils of other land cover types such as wetlands, this may still overestimate the hydraulic conductivity since wetland soils, especially in the humid tropics are generally characterized by a significantly high content of organic matter . Additionally there was no availability of a log -Ψ-log-Θ-relationship wherefore hydraulic conductivities and the Brook-Corey exponent where estimated by bulk density based empirical relations found by Bloemen (1983). Since they are originally related to peat soils in temperate areas and the scattering of the derived values to measured data is relatively high, these parameters are principally problematic.

High uncertainties were also present during soil layer parameterization. The available information contained not much more than the average soil depth of 1.5 m. Because of the relative high sensitivity of the model to soil layer thickness and layer related parameters such as water content at saturation or field capacity this is highly likely to cause incorrectness by calculating matric or preferential flow (source area flow, bypass flow). The presence of an almost impermeable ash layer was used to define the lower limit of the soils as impermeable, even if deep seepage losses could probably minimize the matric and groundwater flow, it could not be considered within this study.

Due to the fact that the soil texture was described as containing coarse fragments the stone fraction within each layer can possibly not be neglected. In Absence of any detailed knowledge about the actual situation at the study site, a moderate amount was set within deeper soil layers.

All in all the soil parameterization is characterized through large uncertainties where the derivation of BEXP is probably the most realistic parameter, except soil water content at different sates (given by Roa-García). For the application of a physical model like Brook90 a higher availability of dedicated knowledge would be desirable.

5.3.1 Canopy parameterization

Brook90 requires a number of canopy or plant specific parameters, which are important for estimating land use effects on hydrologic behaviors . Within this approach, most parameters were derived from the dedicated literature which additionally was based on assumptions concerning the canopy structure. The available QUICK BIRD image of the study site did not have a resolution that allows estimating the canopy structure of the forest sites. Parameters such as maximum LAI or height of the present plants therefore were taken from literature, which mostly refers to Amazonian sites. However, a few studies related to mountainous tropical forest derived information about average tree heights as well as LAI for humid tropical mountainous forests. Since the range of such values is generally high (e.g. average canopy height of such forests varied between 15 and 35 m) the used value is not more than an approximation. Considering that the study site is highly impacted by human activities and the cited values are mostly belonging to undisturbed forest this seems even more arbitrary. Same problematic is generally given for the Albedo or the radiation extinction coefficient which all influence transpiration.

Due to expectable higher homogeneity of pastures or grasslands, the forest canopy parameterization is probably more affected by uncertainties but in general the values for all land cover types were strongly based on existing literature, more than on actual knowledge.

An important parameter like maximum leaf conductance, which besides radiation and soil water availability is assumed to be the main forcing factor of transpiration (Federer, 2002), was derived from a physical relationship (Penman-Monteith equation). For the most part, this is merely a shift of the problem since values which are required for applying this equation were estimated (Bowen-Ratio) or taken from literature (aerodynamic conductance). However, in that special case the annual evapotranspiration of the forested B1 watershed (750 mm) is in agreement with the literature. Bruijnzeel (2004), stated a transpiration of tropical forest caonpys of 900 mm per year.

Another relatively important parameter is the root distribution with soil depth. The rooting depth and its distribution are limiting the depth of plant water availability and therefore transpiration. Jackson et al. (1996), described an empirical solution to calculate the root distribution based on the median rooting depht. Even if the relationship may be quite satisfactory, the median rooting depht for the cover types of the study site was estimated and/or taken from literature.

Furthermore, the very limited knowledge of plant species composition within all study sites was probably limiting the consideration of the hydrologic impacts of the particular biomes. As mentioned before, no differentiation between riparian and natural forest was done. Despite the fact that the information about the particular portion of riparian forest was available, the parameterization had caused another rise of the total amount parameters. Since no additional information except of the portion was available a rise of uncertainty would be the result. However, it is clear that the hydrologic functions of riparian forests do not need to correspond to the functions of a *normal* forest .

Although the model did not show high sensitivities to canopy parameters the combination of these parameters is likely to reveal a different picture. Combalicer et al. (2010) stated high model sensitivities to variations of canopy parameter set to +15% and -15%.

Since canopy parameters are assumed to have significant impacts on the watershed in respect to land use and land use changes, the high uncertainty and limited knowledge of these parameters within the study site is not satisfactory.

5.3.2 Flow parameterization

Flow parameters in Brook90 are generally adaption parameters and some of them (e.g. QFPAR and QFFC) are suggested by Federer (2002), as the main calibrating factor. It is likely that these parameters could be estimated in a more or less proper way by good knowledge of the prevailing processes within the watershed. To give an example, IDEPHT is the maximum depth over which infiltration is distributed and conceptually the depth of vertical macropores. Ranges for IDEPHT are given by Federer (2002), but they are generally related to temperate ecosystems and may therefore not reflect the situation at the study site. The mentioned values however where used as basis and then manually calibrated to the several land cover types. As consequence of the mentioned model structure this was a time consumption process and due to the fact that the resulting discharges are a combination of all cover types, the calibrated values are likely not reflecting global optimums. The same problematic generally is given for all flow parameters. QFPAR and QFFC, both determine the quick flow fraction that is routed directly to the channel (Federer, 2002) and were mostly used to fit the peak response and low flows to the observed discharge. This was done within the range as given by Federer (2002), but the modeled fit is obviously away from being perfect. Again, the way of adapting such parameters to different cover types and combining the results to the total catchment runoff makes it merely impossible to gain global optimums. Despite the fact that most flow parameters showed a local optimum within the sensitivity analysis (and if not the positive NS deviations were below 1% for all cover types), the combination of parameters estimated for different cover types is still problematic. The only flow parameter that showed a positive deviation of more than 1% is GSC and determines the fraction of groundwater storage. This parameter was only applied to the forest setup and despite the positive NS deviation variations of this parameter caused a significantly decrease of the low flow fitting.

5.4 Land use impacts on catchment hydrology

The aim of this study was to parameterize a model which enables the estimation of land use changes and its impacts on the hydrology within the study site. This was done based on several assumptions as well as simplifications concerning the land cover characteristic of the three catchments. These assumptions were mostly related to results of the studies done by Roa-García (2009), who stated that the higher low flows of B1 catchment are likely a result of the higher portion of forests and the higher annual water yield as well as the significant higher amount of flash floods observed at the B2 outlet are a result of the higher amount of grasslands. These grasslands were assumed to produce fast overland flow during most precipitation events because of the high antecedent moisture conditions. Combining this with higher bulk densities caused by cattle trampling, the observed lower porosity and the high precipitation amounts (annual as well as event based) the probability of overland flow is rising significantly. The forest areas at the study site are more diverse and consist of natural, riparian and plantation forest. Several studies have shown that these different forest cover types show significant differences in hydrologic behaviors. These differences among others affect transpiration, peak flow attenuation and infiltration characteristics (Zimmermann and Elsenbeer, 2006; Zimmermann and Elsenbeer, 2009; Bruijnzeel, 1990). It is therefore unlikely that the forest area of the three study sites can be characterized by only one jointed characteristic profile accounting for all dominant hydrologic processes. Due to the desired comparably of the land cover impacts within the different catchments, the forest parameter setup had to be applied to all catchments uniformly and only varied in actual proportion. Since there are clear differences in the land cover distribution (B2 forest is almost completely related to the riparian zone whereas plantation forest appears mainly in B1) the modeled discharges of the forest sites may or may not reflect the actual discharges.

A main assumption which was done is that the three catchments differ mainly in the proportional distribution of land cover types and despite that are comparably in terms of soil geology and climatic conditions. The relatively high occurrence of wetlands within BB in respect to grassland and forest is almost similar to B2 and raises the question why there are more wetlands. Wetlands are generally an expression of several ecologic conditions and the presence of wetlands indicates significant differences of geologic and soil related conditions . It is not logical that the appearance of wetlands does not indicate that the conditions which led to the wetland evolution have no influences of the catchment itself. Or in other words, the hydrologic behaviors which led to the wetland development must be a result of catchment characteristics which differ significantly to the characteristics of comparable *watersheds* without wetlands.

Barbier (1994) resumed that the general comparability of wetlands is problematic since most wetlands show different characteristics. Roa-García showed that some wetlands have an open water table where others not. Some wetlands within the study site have surface outflows where others do have only subsurface outflows. Some are feed by groundwater or springs where for others precipitation seems to be the only water source . These observations probably led to wrong estimations of particular wetland flow contributions because mechanisms that are dominant for one wetland could already be negligible for an adjacent wetland .

Putting these facts together they would probably provide a sufficient explanation of the gap between the modeled and observed data and are limiting the meaningfulness of the modeled results in respect to land cover impacts.

However, the main characteristics of daily and monthly observed discharges are more or less matched by the model and the differences on annual basis are small. While the low season flows are generally not matched correctly, the main shape of the hydrographs were reflected by the model. This indicates, that the assumptions which were made concerning the land cover impacts, could at least partially explain the observed flow behavior

6 Conclusion

The aim of this study was the development of a model that describes the impacts of different land use portions on the runoff behavior of three small tropical headwater catchments. The presence of a smaller and an extended dry season within the study regions caused limited flows in particular during the period between July and September. Given that the streams of these catchments are the main water source for a municipality of 15000 residents and used to supply the needs of all their social and economical activities. The low flow season results in water scarcity for the entire municipality. Since the region belongs to the coffee growing region of Columbia which is subject to persistent changes in terms of land use, the question arises if land use changes within the catchment areas would impact the runoff behaviors. Furthermore it is of special interest if particular alterations of land use are likely to result in decreasing low flows. Previous research which was done within these catchments suggests that the three catchments are principally comparable in terms of geology soils and climate and that the differences in their daily, monthly and annual runoff behavior are mainly a result of differing portions of land cover. Based on this assumption the primary idea consisted of the parameterization of a model that is able to reflect the discharge behaviors of all of the three catchments and that would give an outlook to possible impacts of changing land use portions in turn. Additionally, in a next step it could estimate the possible impacts of changing climatic boundary conditions. Due to limited spatial information, such as digital elevation models, the physical lumped parameter model Brook90 was applied to single land cover compartments and then combined to the catchment discharge. Varying the compartment size then might give an assessment of the impacts on runoff amounts if such changes would be applied within the catchment. The relative limited knowledge of physical parameters which are practicable to describe the dominant hydrologic processes led to the need of determining these variables. Since variables without explicable reference to the characteristics of the study site are likely to result in misinterpretations, the emphasis of this study was to determine these relevant variables as reasonable as possible. In a second step the application of the model was done and tested for observed discharges.

Applying a parameter rich lumped model on single land cover compartments and combining the results to the catchment discharge is in fact the application of one conceptual model containing several hydrologic response units. Due to the fact that each response unit or land use compartment requires a full set of parameters, the amount of parameters needed for the entire model was large. Over all, approximately 150 parameters were defined for three different land use types and another 30 describing the soil characteristics of the plantation forest. The basic knowledge of ranges for the particular parameters was mostly derived from literature or calculated under consideration of depending variables if known. This led to high uncertainties for particular values especially in relation to soils but also to plant related parameters. The combination of single model runs to the particular catchment result revealed further problems. Since Brook90 is designed to account for a single catchment, the calibration of parameters for single land use types leads to subjectivity. The influence of single parameters on the total catchment runoff is hard to estimate if the shown result is only temporary and will be muted by adding the modeled results of the other land use types. Due to the relative contribution of the different cover types to the overall catchment discharge a parameter could increase the model fit for one catchment but did not show any influences within the other catchment. This fact was also observed during the sensitivity analysis which revealed generally low sensitivities of the model to most parameters. This indicates that the interval of 10% which was used to vary single values is relatively small and most of the model reaction got muted by the results of the remaining land use units. However, the presence of higher sensitivities to some soil related parameters increased the uncertainty of the modeled results. Even if soil related values such as water contents at several states of saturation were derived from the observed data, the remaining number of more or less unknown parameters was high. High sensitivities were observed for the layer thickness of single soil layers as well as for the water content within these layers. Despite the fact that water contents were derived from measured data, the information about their spatial distribution (in fact distribution with depth) was not available. Canopy or plant related parameters did not show high sensitivities but are evenly assumed to account evidently for the characteristics of different cover types. However, other studies have shown that the model becomes sensitive to canopy parameters when entire parameter sets are varied . Since the land use characteristic is actually more complex than it could be reflected within this approach it might at least partially explain the relative bad fit of modeled to observed data. The model performance revealed a mixed picture. It can be said that the characteristic of the different catchments were at least partly reflected by the modeled results whereas on daily and seasonal basis the gap between observed and modeled flows were large. On annual basis the model results or its deviations from observed data were in an acceptable range and the Nash-Sutcliffe model efficiency coefficient which is a common efficiency measure for hydrologic simulations showed values that are described as satisfactory by other authors. However, the modeled period was short which generally increases the probability of high Nash-Sutcliffes which in turn attenuates its meaning to this study

In the present study it was tried to combine the distributed or semi-distributed approach with the parametrization of a lumped parameter model. It has been shown that this approach is generally possible and might be contributed to estimate the impacts of land covers and land use changes on hydrology. Nevertheless, the results derived within this study are not satisfactory and are therefore not suitable to assess the impacts of land use changes on the hydrology of the study site. In particular evaluations concerning increasing or decreasing low flows are problematic. Implications concerning changing climatic conditions are likely to be in the range of the model uncertainty. To improve the possibility of assessing such influences the model structure as used in this study should be simplified. On the one hand this implies a model structure that is easier in handling so that calculations are done within one model run instead of combining the results of various runs afterwards. On the other hand it means that the model should probably be reduced to dominant processes within the catchment. This however requires a better understanding of the present situation which probably implies the need of additional field trips. Nonetheless, improved data bases could further increase the performance and basic variables like the classification of soil horizons and particular plant related parameters should be considered within land use catchment studies in general.

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8 Annex

8.1 Daily Discharge BB

Date	Forest	Plant. Forest	Wetland	Grassland	Date	Forest	Plant. Forest	Wetland	Grassland
	Output [mm/d]					Output [mm/d]			
	8,9	7,63	9,38	5,6	06.10.2006	0,62	0,69	1,38	
01.01.2006	8,24	7,05	3,69	3,68	07.10.2006	0,63	0,69	1,36	1,25
02.01.2006	8,39	7,24	7,28	5,05	08.10.2006	0,64	0,69	1,35	1,1
03.01.2006	17,29	26,97	33,81	31,44	09.10.2006	0,7	0,74	1,66	0,96
04.01.2006	21,05	29,85	34,05	43,58	10.10.2006	1,11	1,11	3,19	1,15
05.01.2006	15,95	21,35	25,42	34,14	11.10.2006	0,74	0,78	1,84	3,85
06.01.2006	10,76	9,91	8,17	16,61	12.10.2006	0,8	0,83	2,08	1,76
07.01.2006	10,27	8,49	3,95	9,03	13.10.2006	10,35	21,8	10,74	2,68
08.01.2006	10,46	8,66	7,09	6,2	14.10.2006	5,28	9,81	6,13	34,65
09.01.2006	10,65	8,96	10,91	6,78	15.10.2006	6,74	12,94	8,86	23,46
10.01.2006	12,04	13,03	19,88	13,31	16.10.2006	2,97	3,09	3,01	26,75
11.01.2006	9,81	8,2	3,86	8,54	17.10.2006	3,47	3,18	3,43	14,48
12.01.2006	10,06	8,48	6,09	6,77	18.10.2006	6,32	9,5	10,38	8,85
13.01.2006	9,75	8,15	3,84	4,32	19.10.2006	4,17	4,29	4,24	17,31
14.01.2006	11,01	10,17	17,56	9,95	20.10.2006	4,08	3,62	2,72	11,87
15.01.2006	10,56	10,29	11,9	10,14	21.10.2006	4,17	3,65	2,38	7,33
16.01.2006	9,5	8,14	4,6	7,58	22.10.2006	4,18	3,63	2,32	4,43
17.01.2006	9,54	8,13	5,34	5,96	23.10.2006	6,05	6,54	11,62	2,84
18.01.2006	9,54	8,11	6,75	5,06	24.10.2006	4,32	4	3,55	12,07
19.01.2006	9,84	8,6	11,24	6,85	25.10.2006	4,25	3,74	2,66	6,71
20.01.2006	8,95	7,61	3,67	4,68	26.10.2006	4,32	3,79	2,66	5,29
21.01.2006	9	7,7	5,69	4,78	27.10.2006	4,38	3,82	3,3	3,81
22.01.2006	9,03	7,76	7,64	4,89	28.10.2006	6,28	7,51	12,02	3,32
23.01.2006	8,47	7,24	3,31	3,41	29.10.2006	5,64	7,01	7,54	12,63
24.01.2006	8,3	7,12	3,24	3,08	30.10.2006	8,48	13,86	13,99	11,25
25.01.2006	8,13	6,96	3,17	2,39	31.10.2006	5,99	6,89	6,7	21,58
26.01.2006	7,92	6,78	3,11	1,95	01.11.2006	11,66	18,49	20,36	15,67
27.01.2006	14,41	21,14	31,7	25,79	02.11.2006	6,74	6,75	6,42	28,79
28.01.2006	9,64	10,3	10,39	13,29	03.11.2006	7,26	6,6	8,58	16,75

29.01.2006	8,37	7,4	5,03	9,55	04.11.2006	6,51	5,54	3,23	11,82
30.01.2006	8,6	7,5	6,62	7,4	05.11.2006	6,59	5,59	3,65	6,97
31.01.2006	8,39	7,26	5,23	5,74	06.11.2006	9,38	11,65	19,64	4,96
01.02.2006	8,3	7,16	5,36	4,99	07.11.2006	10,25	15,03	16,42	16,42
02.02.2006	8,31	7,18	6,74	5,03	08.11.2006	22,14	30,79	36,94	19,91
03.02.2006	9,04	8,64	12,81	8,84	09.11.2006	9,25	9,01	9,19	47,66
04.02.2006	23,91	34,5	41,6	44,51	10.11.2006	9,85	9,24	13,66	21,75
05.02.2006	8,61	7,51	3,71	17,97	11.11.2006	13,13	18,04	25,32	14,96
06.02.2006	9,24	7,95	4,9	8,11	12.11.2006	12,77	16,44	20,61	24,19
07.02.2006	9,11	7,8	4,43	5,24	13.11.2006	15,44	21,52	28,31	24,49
08.02.2006	8,96	7,66	4,45	4,08	14.11.2006	12,34	13,21	15,91	30,25
09.02.2006	8,71	7,43	3,56	3,04	15.11.2006	17,16	23,55	33,2	21,46
10.02.2006	8,56	7,29	4,46	2,71	16.11.2006	10,88	8,88	5,02	31,81
11.02.2006	8,27	7,04	3,41	2,05	17.11.2006	11,07	8,84	4,75	15,06
12.02.2006	8,31	7,06	7,42	3,03	18.11.2006	17,96	24,16	40,24	7,45
13.02.2006	7,81	6,63	3,33	1,82	19.11.2006	12,21	11,19	10,22	28,91
14.02.2006	7,58	6,45	3,16	1,85	20.11.2006	11,78	9,59	8,32	16,96
15.02.2006	7,37	6,28	3,09	1,6	21.11.2006	12,94	11,97	18,46	10,58
16.02.2006	7,17	6,09	3,02	1,36	22.11.2006	11,48	9,48	6,9	13,55
17.02.2006	6,95	5,91	2,96	1,18	23.11.2006	11,35	9,17	6,73	9,7
18.02.2006	7,32	6,24	10,52	4,2	24.11.2006	10,99	8,82	3,95	7,41
19.02.2006	7,15	6,29	8,8	4,41	25.11.2006	10,78	8,66	4,2	4,97
20.02.2006	6,61	5,76	5,44	3,89	26.11.2006	10,84	8,72	9,4	3,81
21.02.2006	6,23	5,38	3,02	3,4	27.11.2006	10,21	8,2	3,97	4,68
22.02.2006	6,19	5,38	3,38	3,12	28.11.2006	10,11	8,14	6,81	3,04
23.02.2006	6,05	5,27	2,98	2,36	29.11.2006	10,39	8,6	12,52	3,92
24.02.2006	5,93	5,17	2,92	1,95	30.11.2006	9,39	7,59	3,46	6,55
25.02.2006	5,8	5,05	3,02	1,7	01.12.2006	9,24	7,52	4,18	4,03
26.02.2006	5,82	5,06	5,13	2,27	02.12.2006	9,82	8,28	12,82	4,06
27.02.2006	5,5	4,78	3,12	1,54	03.12.2006	9,68	8,71	11,05	7,15
28.02.2006	5,41	4,7	3,63	1,78	04.12.2006	8,68	7,2	3,69	8,22
01.03.2006	5,4	4,69	5,12	2,37	05.12.2006	8,61	7,19	3,88	5,84
02.03.2006	5,12	4,46	3,5	1,79	06.12.2006	10,29	10,85	18,89	4,52
03.03.2006	4,93	4,3	2,7	1,6	07.12.2006	16,49	25,47	28,59	12,95
04.03.2006	4,83	4,22	2,84	1,58	08.12.2006	14,64	20,01	22,94	29,46

05.03.2006	5,86	5,64	11,33	7,49	09.12.2006	12,05	13,55	15,89	30,8
06.03.2006	5,08	4,93	5,68	4,56	10.12.2006	11,15	10,5	12,33	21,91
07.03.2006	9,34	16,17	17,86	20,76	11.12.2006	10,31	8,64	7,01	15,73
08.03.2006	16,23	26,71	24,96	37,98	12.12.2006	10,94	9,5	12,66	10,24
09.03.2006	7,73	8,65	9,35	21,81	13.12.2006	10,19	8,59	6,72	10,63
10.03.2006	9,02	11,11	15,16	18,87	14.12.2006	11,83	12,15	18,64	8,18
11.03.2006	10,32	14,26	17,53	21,86	15.12.2006	9,87	8,27	4,48	14,14
12.03.2006	7,23	6,21	3,71	11,66	16.12.2006	9,92	8,25	4,92	8,87
13.03.2006	8,64	7,91	12,61	11,13	17.12.2006	9,7	8,05	3,62	6,09
14.03.2006	10,48	13,49	18,57	17,48	18.12.2006	9,59	7,95	5,57	4,02
15.03.2006	7,91	6,95	4,83	10,89	19.12.2006	9,35	7,74	5,14	3,6
16.03.2006	9,47	9,24	14,63	12,79	20.12.2006	10,23	9,04	16,42	2,97
17.03.2006	8,61	7,95	8,12	10,19	21.12.2006	8,84	7,42	4,44	9,11
18.03.2006	8,26	7,11	5,34	7,59	22.12.2006	8,64	7,23	3,36	5,05
19.03.2006	8,18	6,96	4,88	5,41	23.12.2006	8,5	7,12	3,38	4,61
20.03.2006	8,32	7,09	7,5	5,38	24.12.2006	8,34	7	3,93	3,3
21.03.2006	10,23	12,14	19,24	13,72	25.12.2006	8,76	7,41	11,45	2,7
22.03.2006	8,09	7,27	5,31	8,76	26.12.2006	7,97	6,71	4,66	5,6
23.03.2006	11,94	16,04	23,49	20,2	27.12.2006	7,72	6,51	3,79	3,43
24.03.2006	8,41	7,55	5	11,75	28.12.2006	7,52	6,35	3,12	3,45
25.03.2006	8,41	7,22	3,5	6,99	29.12.2006	7,35	6,22	3,12	2,76
26.03.2006	8,51	7,27	5,18	4,94	30.12.2006	7,28	6,15	5,26	2,18
27.03.2006	8,35	7,11	4,95	3,71	31.12.2006	6,95	5,88	3,01	2,37
28.03.2006	8,23	7	5,74	3,53	01.01.2007	6,73	5,69	2,88	1,49
29.03.2006	7,98	6,78	4,83	2,97	02.01.2007	6,54	5,52	2,83	1,45
30.03.2006	8,41	7,27	11,26	5,99	03.01.2007	6,33	5,34	2,78	1,35
31.03.2006	9,98	12,31	17,9	13,5	04.01.2007	6,21	5,24	3,93	1,21
01.04.2006	8,49	8,72	8,68	11,22	05.01.2007	5,92	4,99	2,72	1,43
02.04.2006	7,94	7,03	5,38	8,39	06.01.2007	5,74	4,83	2,67	1,01
03.04.2006	8,64	7,91	10,55	9,18	07.01.2007	5,56	4,68	2,63	1,01
04.04.2006	8,29	7,6	7,78	8,31	08.01.2007	5,38	4,53	2,59	0,97
05.04.2006	10,07	12,14	16,99	15,11	09.01.2007	5,28	4,44	3,53	0,9
06.04.2006	8,55	8,41	7,53	11,51	10.01.2007	5,12	4,31	3,64	1,12
07.04.2006	10,4	11,94	16,73	15,94	11.01.2007	4,86	4,09	2,52	1,16
08.04.2006	12,15	16,88	20,3	21,73	12.01.2007	4,71	3,97	2,48	0,81

09.04.2006	8,55	7,46	3,68	12,09	13.01.2007	4,69	3,95	3,84	0,86
10.04.2006	9,44	8,27	10,44	9,43	14.01.2007	4,99	4,26	7,71	1,33
11.04.2006	9,83	9,18	12,69	10,42	15.01.2007	4,34	3,68	3	4,16
12.04.2006	10,35	10,93	14,28	13,38	16.01.2007	4,28	3,65	3,34	1,55
13.04.2006	8,7	7,54	3,51	8,28	17.01.2007	4,1	3,53	2,49	2,26
14.04.2006	9,34	8,22	9,66	8,04	18.01.2007	4,37	3,8	5,41	1,93
15.04.2006	9,38	8,44	9,73	7,9	19.01.2007	5,23	5,75	9,53	3,4
16.04.2006	11,16	13,6	18,19	15,41	20.01.2007	5,6	7,49	9,08	8,24
17.04.2006	9,1	8,48	6,32	11,02	21.01.2007	4,13	3,85	2,89	9,77
18.04.2006	10,84	11,45	16,98	15,03	22.01.2007	5,13	5,02	7,3	8,15
19.04.2006	17,21	26,22	31,56	32,18	23.01.2007	4,5	4,18	3,12	8,79
20.04.2006	11,5	12,08	12,4	20,82	24.01.2007	5,19	4,94	6,99	5,84
21.04.2006	11,8	12,13	16,09	16,93	25.01.2007	10,92	19,25	20,18	7,38
22.04.2006	10,24	8,92	5,74	10,25	26.01.2007	6,33	7,28	7,12	25,23
23.04.2006	13,42	16,21	24,34	18,94	27.01.2007	5,59	5,07	3,17	16,64
24.04.2006	10,19	8,81	4,37	10,72	28.01.2007	5,75	5,12	3,02	9,09
25.04.2006	11,56	10,67	14,91	11,79	29.01.2007	5,75	5,1	2,96	5,57
26.04.2006	10,34	8,93	5,15	7,69	30.01.2007	5,69	5,02	2,91	3,77
27.04.2006	10,23	8,74	4,91	5,79	31.01.2007	5,59	4,93	2,85	2,77
28.04.2006	15,98	22,25	32,88	24,46	01.02.2007	5,48	4,8	2,8	2,2
29.04.2006	13,2	15,11	15,98	20,37	02.02.2007	5,34	4,67	2,75	1,83
30.04.2006	12,68	13,43	16	18,17	03.02.2007	5,21	4,54	2,69	1,54
01.05.2006	11,17	9,84	7,43	11,53	04.02.2007	5,07	4,42	2,64	1,31
02.05.2006	11,06	9,41	7,02	8,18	05.02.2007	4,91	4,28	2,59	1,14
03.05.2006	11,46	9,97	12,16	8,96	06.02.2007	4,77	4,15	2,53	1
04.05.2006	10,72	9,17	6,24	6,95	07.02.2007	4,63	4,02	2,48	0,88
05.05.2006	10,42	8,83	4,8	5,63	08.02.2007	4,48	3,88	2,43	0,78
06.05.2006	10,52	8,95	8,46	5,91	09.02.2007	4,75	4,11	6,9	0,7
07.05.2006	10,56	9,16	10,28	6,94	10.02.2007	4,29	3,71	3,45	2,71
08.05.2006	9,81	8,36	4,32	5,23	11.02.2007	4,68	4,1	7,45	1,15
09.05.2006	12	13,45	21,1	14,75	12.02.2007	3,99	3,46	2,8	4,36
10.05.2006	10,42	10,17	9,66	12,16	13.02.2007	3,89	3,4	2,5	1,92
11.05.2006	9,9	8,68	6,46	8,33	14.02.2007	4,19	3,7	5,45	2,26
12.05.2006	9,54	8,23	3,49	5,42	15.02.2007	3,79	3,34	2,56	3,69
13.05.2006	9,43	8,11	3,83	4	16.02.2007	6,19	9,04	13,4	2,2

14.05.2006	9,65	8,27	9,66	4,94	17.02.2007	7,13	12,45	11,93	13,36
15.05.2006	9,11	7,83	5,38	3,68	18.02.2007	4,94	5,35	5,63	16,67
16.05.2006	10,41	10,41	17,12	11,37	19.02.2007	11,91	20,36	21,69	12,62
17.05.2006	8,58	7,42	3,39	6,34	20.02.2007	6,11	6,39	6,13	29,82
18.05.2006	9,11	8,1	8,73	7,57	21.02.2007	8,35	10,35	14,93	16,85
19.05.2006	8,98	8,05	8,31	7,27	22.02.2007	6,02	5,23	3,25	17,75
20.05.2006	8,6	7,59	5,78	6,23	23.02.2007	6,27	5,39	3,18	10,25
21.05.2006	11,67	15,29	22,14	18,17	24.02.2007	6,29	5,39	3,1	6,34
22.05.2006	8,31	7,36	3,44	9,72	25.02.2007	6,21	5,31	3,04	3,82
23.05.2006	8,64	7,61	5,01	6,6	26.02.2007	6,08	5,19	2,98	2,75
24.05.2006	8,41	7,37	3,3	4,02	27.02.2007	5,95	5,05	2,92	2,18
25.05.2006	8,47	7,39	6,16	4,17	28.02.2007	5,79	4,91	2,86	1,8
26.05.2006	8,08	7,05	3,4	2,86	01.03.2007	5,63	4,77	2,8	1,48
27.05.2006	7,92	6,9	3,79	2,73	02.03.2007	5,46	4,63	2,75	1,27
28.05.2006	7,68	6,69	3,09	2,13	03.03.2007	5,31	4,48	2,69	1,09
29.05.2006	7,49	6,5	3,2	1,86	04.03.2007	5,57	4,69	7,88	0,96
30.05.2006	7,45	6,46	6,1	2,5	05.03.2007	5,22	4,39	5,26	3,02
31.05.2006	7,05	6,11	3,28	1,55	06.03.2007	5,39	4,63	7,54	2,35
01.06.2006	6,85	5,94	3,3	1,66	07.03.2007	9,63	17,03	20,27	4,41
02.06.2006	6,8	5,88	5,72	2,46	08.03.2007	4,93	4,4	3,26	20,99
03.06.2006	7,8	7,71	14,39	9,77	09.03.2007	8,13	10,51	15,66	10,51
04.06.2006	7,05	7,11	7,87	7,23	10.03.2007	8,22	11,1	13,18	17,05
05.06.2006	6,75	6,42	6,77	8,09	11.03.2007	6,16	5,47	4,18	18,54
06.06.2006	7,68	8,27	11,11	11,48	12.03.2007	6,41	5,52	4,6	11,05
07.06.2006	7,61	8,31	9,6	12,09	13.03.2007	6,45	5,5	4,72	7,01
08.06.2006	10,25	15,19	17,64	20,11	14.03.2007	6,25	5,31	3,14	5,42
09.06.2006	7,09	6,68	4,46	12,63	15.03.2007	6,36	5,39	5,36	3,76
10.06.2006	7,43	6,68	5,47	8,11	16.03.2007	6,64	5,71	8,87	3,9
11.06.2006	7,21	6,4	3,24	4,98	17.03.2007	6,35	5,55	6,62	5,53
12.06.2006	7,14	6,32	3,16	3,7	18.03.2007	6,59	5,99	8,7	5,47
13.06.2006	8,65	8,72	16,99	11,14	19.03.2007	6,03	5,28	4,35	7,54
14.06.2006	8,14	8,65	10,48	10,16	20.03.2007	6,78	6,35	9,99	5,87
15.06.2006	7,84	7,79	8,92	10,66	21.03.2007	7,24	7,73	11,32	8,49
16.06.2006	7,1	6,39	3,67	6,98	22.03.2007	6,54	6,34	6,58	11,18
17.06.2006	7,1	6,35	3,19	4,74	23.03.2007	6,58	6,09	6,66	9,52

18.06.2006	7,03	6,28	3,38	3,24	24.03.2007	6,2	5,52	3,2	8,43
19.06.2006	6,89	6,13	3,29	2,37	25.03.2007	6,23	5,55	3,42	5,7
20.06.2006	6,7	5,94	2,98	1,83	26.03.2007	6,4	5,68	6,11	4,26
21.06.2006	6,95	6,11	9,04	4,12	27.03.2007	6,77	6,2	9,65	4,35
22.06.2006	6,33	5,59	3,03	1,79	28.03.2007	6,81	6,66	9,17	6,42
23.06.2006	6,16	5,43	2,88	1,97	29.03.2007	7,62	8,83	12,4	7,91
24.06.2006	6,26	5,49	6,48	3,09	30.03.2007	6,12	5,59	3,43	12,16
25.06.2006	6,09	5,34	6,13	3,21	31.03.2007	6,82	6,34	8,09	8,03
26.06.2006	5,66	4,97	2,89	2,09	01.04.2007	6,65	6,17	6,57	7,95
27.06.2006	5,51	4,85	2,75	2,05	02.04.2007	6,5	5,95	5,45	6,73
28.06.2006	5,36	4,71	2,65	1,59	03.04.2007	6,91	6,45	8,91	5,92
29.06.2006	5,2	4,58	2,56	1,19	04.04.2007	6,83	6,54	7,94	7,31
30.06.2006	5,04	4,43	2,46	0,92	05.04.2007	6,44	5,98	5,17	7,57
01.07.2006	4,89	4,28	2,37	0,7	06.04.2007	6,28	5,76	3,79	6,41
02.07.2006	4,72	4,13	2,29	0,56	07.04.2007	7,04	6,67	10,47	4,94
03.07.2006	4,55	3,98	2,22	0,45	08.04.2007	6,23	5,75	3,99	7,72
04.07.2006	4,39	3,83	2,15	0,37	09.04.2007	6,13	5,64	3,28	5,22
05.07.2006	4,23	3,69	2,1	0,32	10.04.2007	6,87	6,47	10,19	4,46
06.07.2006	4,07	3,55	2,05	0,27	11.04.2007	9,79	15,46	19,96	7,03
07.07.2006	3,92	3,41	2,01	0,24	12.04.2007	6,68	6,84	5,74	18,51
08.07.2006	3,77	3,28	1,96	0,21	13.04.2007	6,52	6,02	3,35	11,76
09.07.2006	3,63	3,15	1,91	0,18	14.04.2007	6,66	6,08	4,25	7,19
10.07.2006	3,49	3,03	1,86	0,16	15.04.2007	6,58	5,97	3,98	5,2
11.07.2006	3,36	2,91	1,8	0,14	16.04.2007	6,5	5,87	4,18	3,82
12.07.2006	3,27	2,84	2,26	0,23	17.04.2007	6,29	5,68	3,05	3,28
13.07.2006	3,12	2,71	1,9	0,15	18.04.2007	9,84	13,87	23,16	2,55
14.07.2006	2,99	2,59	1,71	0,09	19.04.2007	7,83	9,44	10,02	18,09
15.07.2006	2,87	2,49	1,68	0,09	20.04.2007	10,67	15,98	19,42	12,46
16.07.2006	2,76	2,39	1,63	0,08	21.04.2007	7,32	7,03	5,57	22,07
17.07.2006	2,66	2,3	1,66	0,09	22.04.2007	8,46	8,19	11,99	13,46
18.07.2006	2,55	2,21	1,58	0,07	23.04.2007	7,76	7,12	6,75	12,35
19.07.2006	2,45	2,12	1,54	0,06	24.04.2007	7,87	7,12	7,67	9,16
20.07.2006	2,41	2,09	2,04	0,19	25.04.2007	13,79	21,41	29,27	8,27
21.07.2006	2,33	2,02	2,07	0,25	26.04.2007	10,47	12,7	14,3	26,58
22.07.2006	2,19	1,89	1,58	0,08	27.04.2007	12,17	16,13	21,75	21,06

23.07.2006	2,09	1,8	1,48	0,05
24.07.2006	2,01	1,74	1,48	0,05
25.07.2006	2,37	2,1	4,13	2,22
26.07.2006	2,23	1,96	3,86	3
27.07.2006	3,32	3,24	8,84	15,53
28.07.2006	1,72	1,48	1,99	0,66
29.07.2006	1,65	1,42	1,92	1,87
30.07.2006	1,64	1,41	2,34	2,28
31.07.2006	1,53	1,32	1,84	1,58
01.08.2006	1,49	1,29	1,78	1,28
02.08.2006	1,44	1,25	1,71	0,97
03.08.2006	1,4	1,21	1,66	0,74
04.08.2006	1,36	1,18	1,61	0,58
05.08.2006	1,31	1,14	1,56	0,47
06.08.2006	1,29	1,11	1,67	0,45
07.08.2006	1,23	1,06	1,53	0,34
08.08.2006	1,23	1,07	1,91	0,51
09.08.2006	1,29	1,12	2,59	1,06
10.08.2006	1,1	0,95	1,49	0,25
11.08.2006	1,06	0,91	1,47	0,27
12.08.2006	1,03	0,88	1,42	0,28
13.08.2006	0,99	0,85	1,38	0,26
14.08.2006	1,59	1,43	4,54	4,67
15.08.2006	0,92	0,79	1,54	0,33
16.08.2006	1,04	0,91	2,51	1,58
17.08.2006	0,87	0,74	1,63	0,82
18.08.2006	0,82	0,7	1,49	0,9
19.08.2006	0,8	0,68	1,51	0,94
20.08.2006	0,77	0,65	1,43	0,81
21.08.2006	0,74	0,63	1,39	0,69
22.08.2006	0,72	0,61	1,35	0,57
23.08.2006	0,7	0,59	1,36	0,49
24.08.2006	0,86	0,75	2,41	1,4
25.08.2006	0,64	0,54	1,35	0,39
26.08.2006	0,91	0,8	2,89	2,39
28.04.2007	8,78	7,74	4,73	23,58
29.04.2007	9,75	8,76	11,68	12,6
30.04.2007	9,2	8,04	7,21	10,67
01.05.2007	9,03	7,77	6,32	7,97
02.05.2007	8,93	7,67	6,42	6,58
03.05.2007	8,71	7,46	5,51	5,46
04.05.2007	8,51	7,29	5,08	4,6
05.05.2007	8,8	7,62	10,38	4,03
06.05.2007	8,05	6,9	3,49	5,9
07.05.2007	8,3	7,17	8,17	3,69
08.05.2007	8,03	6,98	6,6	5,24
09.05.2007	7,6	6,57	3,38	4,64
10.05.2007	7,59	6,58	5,06	3,85
11.05.2007	7,3	6,33	3,17	3,76
12.05.2007	7,28	6,31	5,34	2,64
13.05.2007	7,36	6,39	8,15	2,91
14.05.2007	6,79	5,89	3,44	4,08
15.05.2007	6,74	5,86	4,83	2,56
16.05.2007	7,28	6,61	10,84	3,16
17.05.2007	6,45	5,72	4,32	6,57
18.05.2007	8,37	10,25	15,6	4,33
				13,29

27.08.2006	0,61	0,51	1,44	0,6
28.08.2006	0,6	0,5	1,47	0,84
29.08.2006	0,56	0,47	1,34	0,78
30.08.2006	0,57	0,48	1,51	0,87
31.08.2006	0,6	0,51	1,78	1,07
01.09.2006	0,51	0,42	1,3	0,58
02.09.2006	0,5	0,42	1,37	0,66
03.09.2006	0,7	0,61	2,46	2,02
04.09.2006	0,47	0,39	1,36	0,64
05.09.2006	0,44	0,37	1,29	0,71
06.09.2006	0,43	0,36	1,26	0,7
07.09.2006	0,44	0,36	1,36	0,73
08.09.2006	0,85	0,76	3,18	3,86
09.09.2006	0,45	0,38	1,7	1,28
10.09.2006	0,44	0,37	1,71	1,64
11.09.2006	0,38	0,32	1,42	1,43
12.09.2006	0,36	0,29	1,3	1,3
13.09.2006	0,73	0,65	3,05	4,23
14.09.2006	0,37	0,31	1,55	1,73
15.09.2006	0,34	0,28	1,4	2,03
16.09.2006	0,47	0,4	2,09	2,92
17.09.2006	0,36	0,3	1,61	2,21
18.09.2006	0,55	0,47	2,46	3,76
19.09.2006	1,21	1,34	4,47	9,98
20.09.2006	0,38	0,37	1,79	5,6
21.09.2006	0,34	0,35	1,53	4,78
22.09.2006	0,39	0,46	1,6	3,71
23.09.2006	0,49	0,58	1,82	3,05
24.09.2006	0,47	0,57	1,49	2,25
25.09.2006	0,55	0,65	1,69	2,15
26.09.2006	0,54	0,64	1,44	1,53
27.09.2006	0,56	0,66	1,4	1,26
28.09.2006	0,57	0,67	1,37	1,04
29.09.2006	0,62	0,7	1,62	1,11
30.09.2006	0,91	0,94	2,79	2,76

01.10.2006	0,71	0,77	2,03	1,87
02.10.2006	0,59	0,65	1,46	1,45
03.10.2006	0,59	0,66	1,42	1,58
04.10.2006	0,61	0,67	1,4	1,46
05.10.2006				

8.2 Daily discharge B1

Date	Forest	Plant. Forest	Wetland	Grassland	Date	Forest	Plant. Forest	Wetland	Grassland
	Output [mm/d]					Output [mm/d]			
					06.10.2006	0,19	0,16	1,22	
01.01.2006	8,25	6,8	10,81	4,26	07.10.2006	0,19	0,16	1,21	1,26
02.01.2006	7,7	6,37	6,11	2,78	08.10.2006	0,19	0,17	1,19	1,1
03.01.2006	7,92	6,81	9,55	5,73	09.10.2006	0,23	0,2	1,4	0,96
04.01.2006	16,22	24,29	29,34	30,68	10.10.2006	0,68	0,63	3,02	1,09
05.01.2006	17,52	25,35	27,26	38,58	11.10.2006	0,23	0,2	1,45	4,71
06.01.2006	11,87	14,68	16,29	26,49	12.10.2006	0,55	0,51	2,61	1,5
07.01.2006	9,88	9,4	9,25	14,36	13.10.2006	8,47	20,47	9,34	4,6
08.01.2006	9,18	7,59	4,02	8,43	14.10.2006	6,72	13,33	7,14	36,31
09.01.2006	9,13	7,51	3,57	5,43	15.10.2006	8,49	16,62	9,81	31,42
10.01.2006	9,64	8,04	10,88	6,43	16.10.2006	4,73	7,54	6,44	33,97
11.01.2006	9,26	7,81	7,79	5,85	17.10.2006	3,41	3,4	3,87	22,38
12.01.2006	8,71	7,2	3,59	4,6	18.10.2006	4,72	5,23	7,18	12,8
13.01.2006	8,75	7,27	5,55	4,44	19.10.2006	3,97	3,72	4,31	13,27
14.01.2006	8,43	6,99	3,58	3,14	20.10.2006	3,92	3,38	3,2	9,97
15.01.2006	9,56	8,77	15,72	8,9	21.10.2006	3,91	3,33	2,38	6,81
16.01.2006	9,2	9,08	10,85	8,91	22.10.2006	3,93	3,33	2,32	4,27
17.01.2006	8,19	7,03	4,32	6,93	23.10.2006	4,51	3,81	6,69	2,92
18.01.2006	8,26	7,06	5	5,71	24.10.2006	3,99	3,38	3,52	5,6
19.01.2006	8,31	7,09	6,29	4,93	25.10.2006	3,86	3,26	2,82	3,72
20.01.2006	8,65	7,64	10,4	6,82	26.10.2006	3,84	3,25	2,82	3,52
21.01.2006	7,8	6,67	3,5	4,52	27.10.2006	3,87	3,27	3,47	3,08
22.01.2006	7,9	6,79	5,36	4,8	28.10.2006	4,58	4,11	7,7	3,09

23.01.2006	7,97	6,89	7,17	4,73	29.10.2006	4,37	4,23	5,97	7,3
24.01.2006	7,45	6,4	3,18	3,39	30.10.2006	7,68	13,49	13,62	7,33
25.01.2006	7,33	6,31	3,12	3,06	31.10.2006	8,88	15,32	13,6	20,68
26.01.2006	7,19	6,19	3,05	2,39	01.11.2006	19,81	30,69	28,36	25,96
27.01.2006	7,01	6,04	2,99	1,93	02.11.2006	9,54	11,69	13,67	49,09
28.01.2006	13,6	20,71	29,73	25,81	03.11.2006	7,73	7,6	9,5	27,77
29.01.2006	8,82	9,89	9,92	13,23	04.11.2006	6,85	5,61	3,43	15,79
30.01.2006	7,57	6,78	4,86	9,73	05.11.2006	6,99	5,7	4,09	8,37
31.01.2006	7,83	6,86	6,37	7,35	06.11.2006	11,48	15,88	26,1	5,52
01.02.2006	7,65	6,65	5,05	5,71	07.11.2006	16,64	25,92	29,3	21,52
02.02.2006	7,6	6,58	5,18	5,09	08.11.2006	20,39	29,18	36,12	35,55
03.02.2006	7,63	6,61	6,51	4,98	09.11.2006	9,74	8,69	8,86	45,85
04.02.2006	8,35	8,06	12,31	8,75	10.11.2006	11,75	12,18	20,75	19,91
05.02.2006	23,26	34,23	40,13	44,35	11.11.2006	17,39	24,22	34,47	18,68
06.02.2006	8,06	7	3,66	17,99	12.11.2006	13,67	15,92	20,43	33,36
07.02.2006	8,62	7,44	4,82	8,07	13.11.2006	13,18	14,18	19,49	25,99
08.02.2006	8,55	7,32	4,36	5,3	14.11.2006	14,2	16,6	22,84	21,1
09.02.2006	8,42	7,19	4,38	4,06	15.11.2006	18,1	23,76	33,23	22,52
10.02.2006	8,19	6,99	3,51	3,02	16.11.2006	11,7	9,33	5,52	32,49
11.02.2006	8,01	6,83	3,53	2,47	17.11.2006	11,74	9,08	4,44	15,35
12.02.2006	7,82	6,64	3,46	2,01	18.11.2006	18,95	24,91	41,93	7,39
13.02.2006	8,32	7,12	12,51	5,48	19.11.2006	14,56	14,91	17,05	29,33
14.02.2006	7,38	6,27	3,46	2,43	20.11.2006	12,14	9,44	4,49	21,64
15.02.2006	7,19	6,14	3,18	2,73	21.11.2006	12,97	10,47	14,2	10,81
16.02.2006	7,04	6,02	3,11	2,22	22.11.2006	12,7	10,51	11,89	10,29
17.02.2006	6,88	5,89	3,05	1,82	23.11.2006	11,83	9,28	5,19	9,94
18.02.2006	6,69	5,72	2,99	1,5	24.11.2006	11,6	9,09	4,33	7,18
19.02.2006	7,39	6,46	12,54	6,04	25.11.2006	11,39	8,95	5,04	5,13
20.02.2006	9,4	13,42	18,07	14,09	26.11.2006	12,21	10,12	17,44	3,99
21.02.2006	7,36	7,8	7,95	10,58	27.11.2006	10,77	8,49	3,86	9,04
22.02.2006	6,63	5,78	3,23	7,43	28.11.2006	10,83	8,65	7,29	4,96
23.02.2006	6,75	5,9	3,83	5,06	29.11.2006	10,59	8,48	6,8	5,72
24.02.2006	6,65	5,79	3,19	3,5	30.11.2006	10,12	8,06	3,48	5,01
25.02.2006	6,54	5,68	3,12	2,69	01.12.2006	10,12	8,09	7,04	3,79
26.02.2006	6,42	5,57	3,32	2,22	02.12.2006	11,12	10,2	17,06	4,25

27.02.2006	6,75	5,83	8,52	4,25	03.12.2006	10,92	10,93	13,2	10,28
28.02.2006	6,1	5,28	3,15	2,26	04.12.2006	9,43	7,74	3,8	11,7
01.03.2006	5,98	5,19	3,16	2,47	05.12.2006	9,47	7,78	4,41	7,83
02.03.2006	6,56	5,78	9,8	5,52	06.12.2006	11,92	13,46	21,93	5,44
03.03.2006	5,88	5,16	4,34	3,4	07.12.2006	21,45	29,58	36,27	15,75
04.03.2006	5,64	4,94	2,97	3,17	08.12.2006	18,06	24,13	28,93	38,95
05.03.2006	5,6	4,92	3,22	2,81	09.12.2006	14,54	17,26	20,65	37,87
06.03.2006	7,11	7,83	13,93	10,07	10.12.2006	12,18	10,97	10,96	26,53
07.03.2006	6,2	6,5	7,06	7,38	11.12.2006	11,54	9,41	6,97	15,91
08.03.2006	12,55	21,14	23,24	27,17	12.12.2006	12,67	11,43	17,23	9,71
09.03.2006	15,15	23,52	24,7	36,51	13.12.2006	11,61	9,89	8,46	12,49
10.03.2006	9,66	11,77	13,26	22,87	14.12.2006	13,31	13,92	20,09	10,08
11.03.2006	8,32	7,78	8,42	13,57	15.12.2006	11,09	9,14	4,52	15,78
12.03.2006	9,57	10,11	15,17	15,05	16.12.2006	11,22	9,21	6,27	9,57
13.03.2006	7,87	6,71	3,77	9,29	17.12.2006	10,91	8,9	4,08	6,96
14.03.2006	9,94	10,32	17,48	13,54	18.12.2006	10,78	8,8	6,46	4,44
15.03.2006	10,81	13,58	17,28	17,35	19.12.2006	11,49	9,84	16,4	4,09
16.03.2006	8,29	7,12	3,84	10,37	20.12.2006	12,27	13,52	17,7	8,9
17.03.2006	11,33	13,42	21,35	17,13	21.12.2006	10,33	8,89	6,1	13,33
18.03.2006	10,61	11,86	13,96	16,37	22.12.2006	10,11	8,42	3,78	10,4
19.03.2006	8,94	7,7	4,63	9,89	23.12.2006	10	8,31	3,58	6,59
20.03.2006	9,17	7,83	6,56	7	24.12.2006	9,8	8,13	3,7	4,33
21.03.2006	9,1	7,74	6,79	5,74	25.12.2006	9,79	8,1	7,59	3,12
22.03.2006	10,89	11,75	19,42	13,29	26.12.2006	9,29	7,69	4,08	3,73
23.03.2006	8,68	7,46	3,93	7,94	27.12.2006	8,99	7,45	3,35	2,52
24.03.2006	10,29	10,04	15,8	12	28.12.2006	8,74	7,23	3,18	2,49
25.03.2006	8,97	7,94	5,66	8,17	29.12.2006	8,49	7,03	3,1	1,99
26.03.2006	8,73	7,52	3,6	5,82	30.12.2006	8,25	6,82	3,5	1,59
27.03.2006	8,7	7,48	4,16	4,25	31.12.2006	7,96	6,58	3,11	1,35
28.03.2006	8,48	7,28	3,43	2,95	01.01.2007	7,67	6,33	2,9	1,08
29.03.2006	8,51	7,27	6,75	3,32	02.01.2007	7,43	6,13	2,85	0,92
30.03.2006	8,08	6,92	3,61	2,15	03.01.2007	7,17	5,91	2,8	0,86
31.03.2006	9,43	9,17	17,35	10,03	04.01.2007	6,93	5,71	3,06	0,8
01.04.2006	13,32	20,88	24,14	21,8	05.01.2007	6,66	5,49	2,72	0,81
02.04.2006	8,3	7,63	5,19	12,83	06.01.2007	6,44	5,3	2,67	0,69

03.04.2006	8,69	7,6	7,08	8,85	07.01.2007	6,21	5,11	2,63	0,66
04.04.2006	9,33	8,56	11,65	9,93	08.01.2007	5,99	4,93	2,59	0,62
05.04.2006	10,12	10,99	14,59	13,6	09.01.2007	5,83	4,79	3,26	0,59
06.04.2006	12,36	17,68	20,9	21,79	10.01.2007	5,58	4,58	2,66	0,73
07.04.2006	9,44	9,01	7,57	14,24	11.01.2007	5,37	4,41	2,49	0,56
08.04.2006	9,76	8,78	9,92	11	12.01.2007	5,19	4,26	2,45	0,52
09.04.2006	10,91	11,45	16,68	14,48	13.01.2007	5,09	4,18	3,48	0,52
10.04.2006	9,01	7,73	3,57	8,68	14.01.2007	5,31	4,38	7,4	0,8
11.04.2006	10,84	10,62	17,57	12,97	15.01.2007	4,67	3,83	2,63	3,06
12.04.2006	10,85	11,66	14,29	13,98	16.01.2007	4,58	3,76	3,2	0,71
13.04.2006	11,21	12,34	15,23	16,04	17.01.2007	4,38	3,6	2,45	1,29
14.04.2006	9,32	8,06	3,71	9,3	18.01.2007	4,79	4,01	7,09	1,14
15.04.2006	11,94	13,06	20,96	16,02	19.01.2007	6,08	8,01	11,45	3,98
16.04.2006	12,12	14,64	16,86	17,89	20.01.2007	5,89	8,15	8,82	10,5
17.04.2006	13,09	16,37	19,21	21,39	21.01.2007	4,34	3,88	2,77	11,23
18.04.2006	10,53	9,62	7,19	13,4	22.01.2007	5,79	5,78	9,1	7,98
19.04.2006	16,82	23,5	33,2	28,92	23.01.2007	4,75	4,26	3,05	10,22
20.04.2006	17,93	24,44	29,28	33,52	24.01.2007	6,08	6,13	9,58	6,53
21.04.2006	12,75	12,4	12,2	19,78	25.01.2007	12,48	21,79	21,68	9,99
22.04.2006	11,99	10,21	8,92	10,94	26.01.2007	6,75	7,1	6,97	28,33
23.04.2006	11,66	9,7	7,08	7,6	27.01.2007	6,11	5,33	3,26	17,62
24.04.2006	14,47	16,76	25,94	17,88	28.01.2007	6,22	5,39	3,1	9,61
25.04.2006	11,2	9,35	4,06	10,01	29.01.2007	6,21	5,36	3,04	5,37
26.04.2006	14,69	17,12	25,55	18,96	30.01.2007	6,13	5,27	2,98	3,63
27.04.2006	11,49	9,83	5,26	11,01	31.01.2007	6,01	5,16	2,93	2,7
28.04.2006	11,51	9,59	5,25	7,16	01.02.2007	5,88	5,03	2,87	2,17
29.04.2006	16,84	22,09	32,96	24,05	02.02.2007	5,73	4,89	2,81	1,8
30.04.2006	16,27	20,37	22,5	25,33	03.02.2007	5,58	4,75	2,76	1,5
01.05.2006	13,61	13,51	14,01	18,43	04.02.2007	5,42	4,62	2,7	1,29
02.05.2006	12,63	10,86	9,31	11,99	05.02.2007	5,25	4,47	2,65	1,12
03.05.2006	12,34	10,28	7,93	8,82	06.02.2007	5,1	4,33	2,59	0,98
04.05.2006	12,51	10,55	11,29	8,82	07.02.2007	4,94	4,19	2,54	0,87
05.05.2006	11,74	9,7	5,25	6,39	08.02.2007	4,79	4,05	2,49	0,77
06.05.2006	11,51	9,49	4,9	5,19	09.02.2007	4,71	3,98	3,46	0,69
07.05.2006	11,6	9,62	9,51	5,92	10.02.2007	4,62	3,9	4,09	0,9

08.05.2006	12,6	12,21	17,82	11,45	11.02.2007	4,88	4,14	7,83	1,18
09.05.2006	10,84	9,14	4,62	7,69	12.02.2007	4,19	3,54	2,66	4,01
10.05.2006	15,08	19,38	27,6	21,76	13.02.2007	4,06	3,44	2,49	1,03
11.05.2006	11,83	11,33	9,77	15,71	14.02.2007	4,21	3,57	4,79	1,48
12.05.2006	10,98	9,2	3,67	7,68	15.02.2007	3,9	3,32	2,65	2,6
13.05.2006	10,89	9,1	3,7	4,98	16.02.2007	7,02	11,12	15,83	1,62
14.05.2006	10,7	8,91	3,83	3,41	17.02.2007	7,79	13,78	12,87	16,38
15.05.2006	11,09	9,26	13,08	6,13	18.02.2007	5,54	6,38	7,36	17,91
16.05.2006	10,35	8,68	6,41	4,4	19.02.2007	11,32	18,82	20,76	14,9
17.05.2006	11,72	11,9	18,21	12,58	20.02.2007	5,85	5,6	4,96	28,62
18.05.2006	9,7	8,17	3,5	7,33	21.02.2007	8,38	9,88	15,59	15,47
19.05.2006	10,45	9,17	10,68	8,76	22.02.2007	6,1	5,17	3,27	17,37
20.05.2006	9,95	8,64	7,2	7,25	23.02.2007	6,34	5,36	3,2	10,58
21.05.2006	9,53	8,12	4,27	5,49	24.02.2007	6,34	5,35	3,12	6,15
22.05.2006	11,89	13,61	21,17	15,43	25.02.2007	6,27	5,27	3,06	3,76
23.05.2006	9,22	7,91	3,48	8,3	26.02.2007	6,14	5,15	3	2,7
24.05.2006	9,51	8,19	5,84	6,49	27.02.2007	6,01	5,02	2,94	2,14
25.05.2006	9,19	7,87	3,45	4,02	28.02.2007	5,84	4,88	2,88	1,76
26.05.2006	9,11	7,79	4,88	3,76	01.03.2007	5,68	4,74	2,82	1,48
27.05.2006	8,79	7,51	3,33	2,7	02.03.2007	5,51	4,6	2,76	1,25
28.05.2006	8,56	7,32	3,16	2,31	03.03.2007	5,35	4,46	2,78	1,07
29.05.2006	8,34	7,11	3,1	1,91	04.03.2007	5,54	4,6	7,23	0,96
30.05.2006	8,12	6,91	3,64	1,74	05.03.2007	5,22	4,34	5,04	2,59
31.05.2006	7,93	6,74	4,48	1,74	06.03.2007	5,01	4,15	4,33	2,09
01.06.2006	7,61	6,47	3,35	1,34	07.03.2007	15,22	25,63	29,6	2,1
02.06.2006	7,4	6,28	3,77	1,46	08.03.2007	5,09	4,32	3,21	33,74
03.06.2006	7,2	6,1	4,4	1,64	09.03.2007	8,96	11,95	18,06	12,03
04.06.2006	8,79	9,54	17,72	12,09	10.03.2007	11,07	17,09	19,91	19,24
05.06.2006	7,89	8,48	9,31	8,39	11.03.2007	6,67	5,81	4,36	25,92
06.06.2006	7,27	6,86	6,84	9,08	12.03.2007	7,01	5,8	4,49	13,64
07.06.2006	8,87	10,47	13,83	14,22	13.03.2007	7,16	5,92	6,22	7,59
08.06.2006	10,56	15,42	16,87	20,95	14.03.2007	6,84	5,63	3,42	5,98
09.06.2006	13,89	20,81	22,92	30	15.03.2007	6,8	5,6	4,06	4,08
10.06.2006	8,31	7,52	5,24	15,44	16.03.2007	6,76	5,56	5,06	3,59
11.06.2006	8,68	7,48	6,82	9,16	17.03.2007	6,61	5,43	4,8	3,34

12.06.2006	8,33	7,06	3,54	5,67	18.03.2007	6,75	5,59	8,08	3,05
13.06.2006	8,23	6,96	3,36	4,08	19.03.2007	6,6	5,54	7,27	4,53
14.06.2006	9,28	8,2	16,12	9,5	20.03.2007	6,26	5,23	4,87	4,93
15.06.2006	9,19	9,27	12,08	10,2	21.03.2007	6,49	5,55	7,94	4,5
16.06.2006	8,91	8,66	10,35	11,19	22.03.2007	6,46	5,68	7,46	6,01
17.06.2006	8	6,9	3,84	7,32	23.03.2007	6,37	5,67	6,99	6,45
18.06.2006	7,97	6,85	3,33	4,99	24.03.2007	5,91	5,08	3,25	6,89
19.06.2006	7,86	6,76	3,34	3,3	25.03.2007	5,91	5,1	3,28	5,09
20.06.2006	7,69	6,59	3,15	2,31	26.03.2007	6,02	5,19	5,2	4
21.06.2006	7,5	6,4	3,09	1,81	27.03.2007	6,1	5,28	6,74	3,83
22.06.2006	7,67	6,52	9,42	3,96	28.03.2007	6,13	5,42	7,49	4,37
23.06.2006	7,05	6	3,06	1,69	29.03.2007	7,84	10,02	15,5	5,35
24.06.2006	6,86	5,84	2,98	1,9	30.03.2007	5,86	5,46	4,46	13,37
25.06.2006	6,77	5,76	4,89	2,22	31.03.2007	6,23	5,66	6,37	8,77
26.06.2006	6,44	5,48	2,88	1,41	01.04.2007	6,4	5,81	7,38	7,77
27.06.2006	6,26	5,32	2,81	1,34	02.04.2007	6,25	5,64	6,04	7,18
28.06.2006	6,06	5,15	2,73	1,14	03.04.2007	6,38	5,79	7,23	6,4
29.06.2006	5,86	4,97	2,64	0,93	04.04.2007	6,55	6,11	8,16	6,79
30.06.2006	5,67	4,8	2,55	0,73	05.04.2007	7,22	7,66	11,51	7,43
01.07.2006	5,47	4,63	2,45	0,57	06.04.2007	6,12	5,65	4,27	10,75
02.07.2006	5,28	4,46	2,36	0,47	07.04.2007	8,16	9,55	15,33	7,66
03.07.2006	5,09	4,3	2,28	0,38	08.04.2007	6,25	5,77	3,68	14,02
04.07.2006	4,9	4,13	2,21	0,31	09.04.2007	6,36	5,81	3,22	8,63
05.07.2006	4,72	3,98	2,15	0,26	10.04.2007	6,9	6,27	8,29	5,97
06.07.2006	4,54	3,82	2,1	0,23	11.04.2007	14,96	24,51	31,08	6,19
07.07.2006	4,37	3,68	2,05	0,2	12.04.2007	8,12	8,43	8,74	30,21
08.07.2006	4,2	3,54	2,01	0,17	13.04.2007	7,3	6,45	3,69	17,41
09.07.2006	4,04	3,4	1,96	0,15	14.04.2007	7,48	6,59	4,91	9,07
10.07.2006	3,89	3,27	1,9	0,13	15.04.2007	7,34	6,43	3,98	6,19
11.07.2006	3,74	3,14	1,85	0,12	16.04.2007	7,27	6,35	4,5	4,2
12.07.2006	3,6	3,02	1,8	0,1	17.04.2007	7,03	6,14	3,23	3,62
13.07.2006	3,48	2,92	2,04	0,14	18.04.2007	9,95	12,63	23,43	2,69
14.07.2006	3,32	2,79	1,73	0,08	19.04.2007	7,99	8,7	9,18	16,13
15.07.2006	3,2	2,68	1,72	0,08	20.04.2007	11,11	16,08	20,82	10,89
16.07.2006	3,07	2,57	1,66	0,06	21.04.2007	7,92	7,59	6,36	20,75

17.07.2006	2,95	2,47	1,62	0,06	22.04.2007	8,47	7,72	9,85	13,58
18.07.2006	2,84	2,37	1,59	0,05	23.04.2007	8,05	7,11	6,12	10,81
19.07.2006	2,72	2,28	1,56	0,05	24.04.2007	8,15	7,17	7,49	7,83
20.07.2006	2,62	2,19	1,53	0,04	25.04.2007	12,09	17,07	25,69	7,24
21.07.2006	2,62	2,21	2,54	0,32	26.04.2007	11,23	14,67	17,24	21,04
22.07.2006	2,44	2,04	1,66	0,09	27.04.2007	10,67	12,09	15,52	21,29
23.07.2006	2,34	1,95	1,62	0,07	28.04.2007	8,9	7,88	5,68	18,92
24.07.2006	2,23	1,86	1,48	0,03	29.04.2007	9,38	8,26	9,49	11,11
25.07.2006	2,14	1,79	1,45	0,03	30.04.2007	9,07	7,89	7,21	9,1
26.07.2006	2,58	2,23	4,51	2,69	01.05.2007	8,84	7,59	5,76	7,31
27.07.2006	2,56	2,22	4,98	5,43	02.05.2007	8,69	7,45	5,41	5,81
28.07.2006	3,43	4,1	8,95	15,17	03.05.2007	8,42	7,2	3,87	4,8
29.07.2006	1,84	1,54	2,08	0,75	04.05.2007	8,34	7,13	5,28	3,63
30.07.2006	1,76	1,47	1,97	1,98	05.05.2007	8,55	7,35	10	3,53
31.07.2006	1,71	1,43	2,11	2,21	06.05.2007	7,85	6,72	3,64	5,16
01.08.2006	1,63	1,38	1,88	1,61	07.05.2007	7,99	6,88	7,38	3,23
02.08.2006	1,58	1,34	1,81	1,24	08.05.2007	7,78	6,74	6,54	4,62
03.08.2006	1,53	1,3	1,75	0,93	09.05.2007	7,44	6,42	4,31	4,44
04.08.2006	1,49	1,27	1,7	0,71	10.05.2007	7,36	6,38	5,18	3,81
05.08.2006	1,44	1,23	1,65	0,56	11.05.2007	7,07	6,12	3,24	3,86
06.08.2006	1,39	1,19	1,6	0,45	12.05.2007	7,1	6,15	5,91	2,84
07.08.2006	1,42	1,22	2,29	0,72	13.05.2007	6,85	5,94	4,54	3,34
08.08.2006	1,3	1,11	1,59	0,34	14.05.2007	6,57	5,7	3,01	2,68
09.08.2006	1,26	1,07	1,57	0,32	15.05.2007	6,78	5,88	7,71	2,19
10.08.2006	1,3	1,11	2,27	0,71	16.05.2007	6,98	6,35	9,66	3,92
11.08.2006	1,17	0,99	1,51	0,27	17.05.2007	6,17	5,44	3,74	5,95
12.08.2006	1,13	0,95	1,49	0,27	18.05.2007	11,15	18,17	23,38	4,14
13.08.2006	1,09	0,92	1,44	0,26					22,35
14.08.2006	1,05	0,89	1,39	0,23					
15.08.2006	1,25	1,08	2,89	1,28					
16.08.2006	0,97	0,82	1,44	0,21					
17.08.2006	1,14	0,99	2,69	1,46					
18.08.2006	0,92	0,78	1,61	0,44					
19.08.2006	0,87	0,73	1,46	0,39					
20.08.2006	0,84	0,71	1,48	0,48					

21.08.2006	0,81	0,68	1,4	0,45
22.08.2006	0,78	0,65	1,35	0,4
23.08.2006	0,75	0,63	1,31	0,35
24.08.2006	0,72	0,6	1,28	0,31
25.08.2006	0,72	0,6	1,42	0,36
26.08.2006	0,67	0,56	1,27	0,26
27.08.2006	0,76	0,65	1,94	0,76
28.08.2006	0,62	0,52	1,28	0,23
29.08.2006	0,6	0,5	1,27	0,24
30.08.2006	0,58	0,48	1,21	0,22
31.08.2006	0,56	0,47	1,22	0,23
01.09.2006	0,59	0,49	1,5	0,41
02.09.2006	0,51	0,43	1,16	0,18
03.09.2006	0,5	0,41	1,16	0,18
04.09.2006	0,73	0,64	2,32	1,46
05.09.2006	0,47	0,39	1,26	0,25
06.09.2006	0,44	0,37	1,17	0,2
07.09.2006	0,42	0,35	1,14	0,22
08.09.2006	0,44	0,37	1,3	0,36
09.09.2006	0,74	0,67	2,58	2,44
10.09.2006	0,48	0,41	1,73	1,18
11.09.2006	0,39	0,33	1,37	0,6
12.09.2006	0,36	0,3	1,25	0,59
13.09.2006	0,34	0,28	1,21	0,63
14.09.2006	0,33	0,27	1,21	0,64
15.09.2006	0,33	0,28	1,27	0,68
16.09.2006	0,34	0,29	1,37	0,77
17.09.2006	0,42	0,36	1,77	1,34
18.09.2006	0,31	0,26	1,35	0,8
19.09.2006	0,37	0,32	1,66	1,35
20.09.2006	0,94	0,86	3,67	7,38
21.09.2006	0,29	0,24	1,53	2,22
22.09.2006	0,25	0,2	1,33	2,72
23.09.2006	0,25	0,21	1,4	2,57
24.09.2006	0,27	0,23	1,54	2,42

25.09.2006	0,22	0,18	1,28	1,79
26.09.2006	0,24	0,2	1,42	1,78
27.09.2006	0,21	0,17	1,24	1,3
28.09.2006	0,21	0,17	1,21	1,09
29.09.2006	0,21	0,17	1,18	0,9
30.09.2006	0,22	0,19	1,3	0,91
01.10.2006	0,69	0,64	3,11	4,66
02.10.2006	0,22	0,18	1,39	1,19
03.10.2006	0,19	0,16	1,27	1,62
04.10.2006	0,19	0,16	1,25	1,68
05.10.2006	0,19	0,16	1,24	1,48

8.3 Daily discharge B2

Date	Forest	Plant. Forest	Wetland	Grassland	Date	Forest	Plant. Forest	Wetland	Grassland
	Output [mm/d]					Output [mm/d]			
	8,22	6,76	8,05		06.10.2006	0,11	0,1	1,13	
01.01.2006	7,79	6,4	5,13	2,43	07.10.2006	0,11	0,1	1,12	1,36
02.01.2006	7,82	6,45	8,29	1,77	08.10.2006	0,1	0,1	1,1	1,18
03.01.2006	16,27	26,11	32,08	3,63	09.10.2006	0,13	0,13	1,25	1,03
04.01.2006	19,53	27,89	30,92	30,4	10.10.2006	0,17	0,17	1,44	1,1
05.01.2006	13,44	17,58	20,16	40	11.10.2006	0,11	0,11	1,15	1,32
06.01.2006	10,13	9,67	9,72	29,61	12.10.2006	0,29	0,3	1,92	0,9
07.01.2006	9,47	7,75	5,18	16,48	13.10.2006	6,98	18,83	8,86	2,35
08.01.2006	9,31	7,52	3,65	9,35	14.10.2006	4,3	10,4	5,35	40,44
09.01.2006	9,47	7,66	7,17	5,84	15.10.2006	6,36	14,75	7,99	24,36
10.01.2006	9,7	8,04	11,12	5,14	16.10.2006	1,95	3,01	3,31	30,94
11.01.2006	8,84	7,15	3,55	6,54	17.10.2006	2,23	2,36	3,16	16,74
12.01.2006	9,44	7,94	11,5	4,52	18.10.2006	2,45	2,46	3,38	10,02
13.01.2006	8,66	7,11	4,43	7,18	19.10.2006	2,61	2,55	3,53	7,93
14.01.2006	9,58	8,61	13,59	4,78	20.10.2006	2,49	2,38	2,27	6,79
15.01.2006	9,97	10,36	13,8	8,91	21.10.2006	2,54	2,42	2,02	4,75
16.01.2006	9,01	8,19	7,6	11,64	22.10.2006	2,58	2,43	1,97	3,39
17.01.2006	8,86	7,64	6,67	9,92	23.10.2006	3,5	3,31	6,63	2,39

18.01.2006	8,62	7,29	4,83	7,92	24.10.2006	2,55	2,38	2,08	7,23
19.01.2006	8,61	7,28	5,83	5,79	25.10.2006	2,61	2,44	2,24	3
20.01.2006	8,26	6,96	3,34	4,98	26.10.2006	2,79	2,6	3,34	3,4
21.01.2006	8,1	6,83	3,27	3,47	27.10.2006	2,92	2,7	3,93	3,65
22.01.2006	8,09	6,81	5,6	2,91	28.10.2006	3,22	3,1	4,96	4,19
23.01.2006	7,71	6,5	3,17	3	29.10.2006	4,96	7,94	8,93	6,18
24.01.2006	7,53	6,34	3,11	2,05	30.10.2006	8,28	16,22	12,18	14,09
25.01.2006	7,32	6,17	3,04	1,95	31.10.2006	8,52	14,94	12,33	26,21
26.01.2006	7,1	5,98	2,98	1,66	01.11.2006	14,34	22,74	20,83	28,19
27.01.2006	9,3	10,66	20,51	1,43	02.11.2006	10,78	16,41	16,65	40,06
28.01.2006	7,56	7,7	7,42	13,51	03.11.2006	7,71	8,56	9,94	31,47
29.01.2006	7,17	6,46	5,94	6,38	04.11.2006	6,44	5,3	3,32	18,85
30.01.2006	6,99	6,09	4,33	7,05	05.11.2006	6,63	5,43	3,85	9,34
31.01.2006	6,94	6,02	4,07	5,63	06.11.2006	12,34	18,42	27,09	5,87
01.02.2006	7,06	6,12	5,96	4,56	07.11.2006	11,03	14,63	17,03	24,69
02.02.2006	6,84	5,94	4,72	4,65	08.11.2006	19,02	27,07	34,49	23,88
03.02.2006	8,1	8,32	13,57	3,95	09.11.2006	8,74	7,62	6,38	42,27
04.02.2006	20,46	31,03	34,66	9,94	10.11.2006	9,75	8,32	12,65	18,43
05.02.2006	7,37	6,46	3,54	40,31	11.11.2006	13,19	17,7	26,34	12,83
06.02.2006	8,17	7,12	6,02	17,31	12.11.2006	10,81	11,13	13,23	23,27
07.02.2006	7,96	6,86	4,33	8,99	13.11.2006	10,79	10,23	14,22	18,14
08.02.2006	8,01	6,89	6	5,58	14.11.2006	11,81	12,8	18,39	15,35
09.02.2006	7,67	6,57	3,33	4,93	15.11.2006	16,33	22,91	30,9	17,66
10.02.2006	7,63	6,53	4,69	3,47	16.11.2006	10,22	8,4	4,91	30,36
11.02.2006	7,38	6,31	3,51	3,32	17.11.2006	10,39	8,3	4,15	14,71
12.02.2006	8,18	7,24	13,47	2,46	18.11.2006	18,29	25,13	41,27	7,31
13.02.2006	7,02	6,02	3,34	7,18	19.11.2006	12,4	12,01	12,77	30,74
14.02.2006	6,92	5,97	3,16	3,43	20.11.2006	10,92	8,66	3,99	19,3
15.02.2006	6,82	5,91	3,09	3,79	21.11.2006	11,34	9,13	10,19	9,71
16.02.2006	6,69	5,78	3,03	2,64	22.11.2006	11,64	9,88	13,76	7,97
17.02.2006	6,51	5,63	2,97	2,07	23.11.2006	10,5	8,38	3,74	9,6
18.02.2006	6,88	5,94	9,28	1,7	24.11.2006	10,43	8,36	4,46	6,33
19.02.2006	7,25	6,76	11,29	4,14	25.11.2006	10,28	8,27	5,58	5,05
20.02.2006	6,93	7,05	8,65	6,82	26.11.2006	10,97	9,24	15,82	3,96

21.02.2006	6,06	5,37	3,09	7,5	27.11.2006	9,81	8,02	5,23	8,41
22.02.2006	6,12	5,46	3,12	5,7	28.11.2006	9,99	8,26	8,98	5,36
23.02.2006	6,07	5,41	2,96	4,53	29.11.2006	9,66	7,99	6,98	6,77
24.02.2006	5,99	5,32	2,9	3,11	30.11.2006	9,19	7,53	3,46	5,98
25.02.2006	5,86	5,21	2,93	2,35	01.12.2006	9,63	8,04	10,75	4,47
26.02.2006	5,94	5,24	5,51	1,93	02.12.2006	9,43	8,08	9,29	6,46
27.02.2006	5,57	4,92	2,81	2,59	03.12.2006	9,09	7,76	7,52	6,84
28.02.2006	5,45	4,81	2,9	1,57	04.12.2006	8,61	7,2	3,87	6,92
01.03.2006	6,91	7,06	14,53	1,68	05.12.2006	8,51	7,13	4,24	5,09
02.03.2006	5,48	5,23	4,68	9,95	06.12.2006	9,19	7,99	12,78	4,15
03.03.2006	5,19	4,7	2,86	4,3	07.12.2006	14,76	22,96	28,46	7,72
04.03.2006	5,22	4,73	2,88	4,23	08.12.2006	11,71	14,18	16,06	26,19
05.03.2006	6,43	6,35	11,64	3,38	09.12.2006	13,9	19,06	23,9	22,89
06.03.2006	5,85	6,09	6,81	8,54	10.12.2006	9,94	8,96	7,49	26,94
07.03.2006	7,2	9,19	11,96	7,04	11.12.2006	9,81	8,18	6,18	15,56
08.03.2006	8,92	13,81	14,91	12,96	12.12.2006	11	10,09	16,08	8,96
09.03.2006	6,8	7,34	7,41	19,61	13.12.2006	10,04	8,89	8,24	12,07
10.03.2006	6,89	6,64	7,5	14,18	14.12.2006	12,98	16,29	23,37	9,9
11.03.2006	8,96	11,3	15,72	10,75	15.12.2006	9,75	8,33	4,77	19,66
12.03.2006	6,51	5,9	3,28	16,4	16.12.2006	10,48	8,99	10,48	11,49
13.03.2006	8,96	10,13	16,08	9,84	17.12.2006	9,85	8,25	5,51	9,55
14.03.2006	9,96	13,66	16,15	14,54	18.12.2006	10,95	10,02	16,19	6,56
15.03.2006	7,2	6,46	3,41	18,51	19.12.2006	13,02	16,4	22,25	11,03
16.03.2006	14,01	21,16	29,06	11,36	20.12.2006	14,7	20,19	23,6	19,49
17.03.2006	10,4	11,83	13,29	26,92	21.12.2006	10,4	9,08	5,96	26,4
18.03.2006	8,33	7,27	3,71	20,28	22.12.2006	10,52	8,8	6,17	14,3
19.03.2006	8,71	7,57	6,55	10,36	23.12.2006	10,27	8,51	4,21	8,31
20.03.2006	8,37	7,21	3,46	7,15	24.12.2006	10,04	8,32	3,56	5,34
21.03.2006	9,29	8,35	13,99	4,48	25.12.2006	10,04	8,3	7,42	3,8
22.03.2006	8,11	6,99	3,56	8,38	26.12.2006	9,54	7,89	3,56	4,04
23.03.2006	9,01	8,23	12,62	4,85	27.12.2006	9,29	7,67	3,48	2,66
24.03.2006	8,16	7,25	5,38	8,47	28.12.2006	9,02	7,45	3,3	2,46
25.03.2006	7,89	6,9	3,36	6,14	29.12.2006	8,77	7,23	3,22	1,99
26.03.2006	7,91	6,92	4,7	4,82	30.12.2006	8,5	7,01	3,39	1,58

27.03.2006	7,65	6,68	3,22	3,93	31.12.2006	8,21	6,76	3,07	1,3
28.03.2006	7,72	6,72	6,72	2,68	01.01.2007	7,91	6,52	3,01	1,04
29.03.2006	7,34	6,4	3,95	3,33	02.01.2007	7,66	6,29	2,95	0,92
30.03.2006	8,21	7,55	13,83	2,27	03.01.2007	7,39	6,07	2,9	0,84
31.03.2006	8	8,2	10,07	7,91	04.01.2007	7,13	5,86	2,85	0,77
01.04.2006	7,01	6,29	4,08	7,88	05.01.2007	6,88	5,64	2,8	0,72
02.04.2006	7,34	6,64	6,94	6,16	06.01.2007	6,62	5,43	2,83	0,67
03.04.2006	7,74	7,33	9,6	6,47	07.01.2007	6,39	5,23	2,71	0,64
04.04.2006	7,96	8,14	10,25	7,69	08.01.2007	6,17	5,05	2,67	0,59
05.04.2006	9,22	11,69	14,7	9,9	09.01.2007	6	4,91	3,32	0,56
06.04.2006	7,44	7,13	5,38	15,26	10.01.2007	5,72	4,68	2,61	0,68
07.04.2006	7,43	6,73	4,38	10,49	11.01.2007	5,53	4,52	2,57	0,5
08.04.2006	7,71	6,95	7,32	7,04	12.01.2007	5,34	4,36	2,53	0,5
09.04.2006	7,23	6,48	3,19	6,39	13.01.2007	5,51	4,52	6,99	0,49
10.04.2006	9,59	11,39	19,74	4,08	14.01.2007	4,99	4,09	2,96	2,22
11.04.2006	8,83	10,25	11,44	14,65	15.01.2007	4,8	3,92	2,6	0,69
12.04.2006	9,08	10,15	12,63	13,03	16.01.2007	4,72	3,85	3,37	0,75
13.04.2006	7,51	6,78	3,46	14,84	17.01.2007	4,5	3,68	2,54	1,13
14.04.2006	7,94	7,16	6,64	8,76	18.01.2007	5,42	4,88	10,8	0,88
15.04.2006	8,61	8,19	11,84	7,01	19.01.2007	7,19	11,96	13,49	7,07
16.04.2006	9,16	10,19	12,9	8,98	20.01.2007	5,51	6,52	7,05	13,29
17.04.2006	8,37	8,35	8,14	12,2	21.01.2007	4,65	4,04	2,86	10,9
18.04.2006	11,51	15,94	21,27	11,02	22.01.2007	5,82	5,49	8,91	7,9
19.04.2006	8,97	9,25	8,85	20,61	23.01.2007	5,13	4,61	4,28	9,22
20.04.2006	8,8	8,08	7,84	14,49	24.01.2007	6,33	6,54	10,25	6,68
21.04.2006	8,57	7,67	6,17	10,25	25.01.2007	10,07	16,81	18,2	10,51
22.04.2006	8,42	7,46	5,28	7,35	26.01.2007	6,2	6,22	5,61	22,51
23.04.2006	10,27	11,24	18,56	5,56	27.01.2007	6	5,24	3,15	14,37
24.04.2006	8,11	7,24	3,65	13,37	28.01.2007	6,09	5,27	3,09	7,99
25.04.2006	11,03	13,71	20,26	7,6	29.01.2007	6,07	5,23	3,03	5,1
26.04.2006	8,41	7,73	4,61	16,52	30.01.2007	5,98	5,15	2,97	3,49
27.04.2006	8,54	7,61	4,62	9,77	31.01.2007	5,89	5,05	3,17	2,63
28.04.2006	9,95	9,94	15,63	6,76	01.02.2007	5,75	4,91	2,95	2,19
29.04.2006	11,87	16,86	19,82	11,27	02.02.2007	5,6	4,78	2,89	1,8

30.04.2006	9,57	9,65	8,87	18,4	03.02.2007	5,44	4,63	2,76	1,55
01.05.2006	9,36	8,49	7,94	14,66	04.02.2007	5,3	4,5	2,7	1,33
02.05.2006	9,34	8,38	8,31	10,25	05.02.2007	5,14	4,37	2,65	1,16
03.05.2006	9,38	8,46	9,13	8,63	06.02.2007	4,99	4,23	2,59	1,02
04.05.2006	8,87	7,84	5,14	8,36	07.02.2007	4,84	4,1	2,54	0,9
05.05.2006	8,73	7,68	4,73	6,39	08.02.2007	4,69	3,96	2,49	0,79
06.05.2006	8,92	7,88	8,59	5,21	09.02.2007	4,55	3,85	2,8	0,72
07.05.2006	9,54	9,26	13,43	5,94	10.02.2007	4,52	3,81	4	0,73
08.05.2006	8,31	7,41	4,18	9,57	11.02.2007	4,98	4,27	9,12	1,11
09.05.2006	11,26	14,54	21,42	6,64	12.02.2007	4,1	3,46	2,62	5,2
10.05.2006	9,54	10,03	10,42	17,3	13.02.2007	3,99	3,37	2,51	1,03
11.05.2006	8,54	7,57	3,49	13,9	14.02.2007	4,63	4,07	8,18	1,65
12.05.2006	8,53	7,55	3,41	8,15	15.02.2007	3,84	3,29	2,64	5,41
13.05.2006	8,39	7,41	3,32	5,23	16.02.2007	9,28	17,17	18,97	2,42
14.05.2006	8,53	7,48	7,95	3,36	17.02.2007	10,1	17,21	16,08	22,17
15.05.2006	8,32	7,3	7,15	3,97	18.02.2007	6,07	6,68	7,48	26,33
16.05.2006	9,79	10,71	17,88	3,9	19.02.2007	9,31	13,8	17,57	16,99
17.05.2006	7,67	6,8	3,35	12,54	20.02.2007	5,86	5,11	3,76	22,58
18.05.2006	9,19	9,34	14,02	6,85	21.02.2007	8,19	8,86	15,03	12,44
19.05.2006	8,05	7,48	5,89	11,6	22.02.2007	6,26	5,3	3,3	15
20.05.2006	7,77	6,97	3,42	8,35	23.02.2007	6,44	5,45	3,23	8,84
21.05.2006	8,8	8,23	12,96	5,93	24.02.2007	6,44	5,44	3,15	5,99
22.05.2006	7,62	6,82	3,3	9,09	25.02.2007	6,36	5,35	3,08	3,7
23.05.2006	7,69	6,9	4,66	5,28	26.02.2007	6,22	5,23	3,03	2,69
24.05.2006	7,47	6,69	3,26	4,75	27.02.2007	6,09	5,09	2,96	2,15
25.05.2006	7,32	6,55	3,38	3,19	28.02.2007	5,91	4,96	2,9	1,76
26.05.2006	7,14	6,37	3,05	2,69	01.03.2007	5,75	4,81	2,84	1,46
27.05.2006	6,95	6,19	2,99	2,14	02.03.2007	5,58	4,66	2,79	1,25
28.05.2006	6,76	6,01	2,93	1,77	03.03.2007	5,51	4,59	4,19	1,08
29.05.2006	6,56	5,83	2,95	1,5	04.03.2007	5,39	4,48	4,66	1,35
30.05.2006	6,42	5,69	4	1,29	05.03.2007	5,22	4,34	4,58	1,54
31.05.2006	6,16	5,46	2,99	1,39	06.03.2007	4,94	4,1	2,99	1,69
01.06.2006	6,02	5,32	3,72	1,02	07.03.2007	10,6	17,16	24,53	1,25
02.06.2006	5,74	5,08	2,7	1,22	08.03.2007	4,79	4,12	3,09	24,59

03.06.2006	7,32	7,59	16,46	0,89	09.03.2007	11,83	18,65	24,13	7,59
04.06.2006	5,98	6,11	6,36	11,51	10.03.2007	12,77	19,46	21,76	26,81
05.06.2006	5,84	5,54	6,39	4,98	11.03.2007	6,61	5,64	3,94	31,76
06.06.2006	8,42	12,52	15,79	6,75	12.03.2007	7,04	5,82	4,52	14,58
07.06.2006	7,84	10,42	11,39	16,37	13.03.2007	7,55	6,35	9,53	7,93
08.06.2006	12,64	20,28	22,48	16,89	14.03.2007	6,9	5,68	3,58	7,41
09.06.2006	7,62	7,84	7,69	29,09	15.03.2007	8,24	7,78	14,95	4,99
10.06.2006	7,92	7,39	9,17	17,66	16.03.2007	7,44	6,85	8	10,46
11.06.2006	7,22	6,32	3,48	12,08	17.03.2007	6,87	5,77	3,38	8,82
12.06.2006	7,23	6,31	3,3	7,24	18.03.2007	7,1	6,01	5,74	6,47
13.06.2006	8,21	7,42	14,01	4,91	19.03.2007	7,15	6,07	6,91	5,79
14.06.2006	8,33	8,52	12,21	8,81	20.03.2007	6,81	5,75	4,09	5,13
15.06.2006	7,19	6,44	4,59	10,47	21.03.2007	7,9	7,45	14,14	4,13
16.06.2006	7,09	6,27	3,28	7,74	22.03.2007	6,96	6,29	6,15	9,54
17.06.2006	7,05	6,21	3,2	5,41	23.03.2007	6,91	6,08	6,1	7,04
18.06.2006	6,92	6,08	3,12	3,65	24.03.2007	6,61	5,71	3,27	6,92
19.06.2006	6,77	5,93	3,03	2,53	25.03.2007	6,59	5,7	3,5	4,92
20.06.2006	6,58	5,76	2,97	1,9	26.03.2007	6,72	5,81	6,31	3,82
21.06.2006	6,39	5,58	2,91	1,5	27.03.2007	6,83	5,97	8,1	4,07
22.06.2006	6,19	5,38	2,84	1,27	28.03.2007	6,7	5,96	7,48	5,04
23.06.2006	6	5,21	2,77	1,06	29.03.2007	7,21	7,05	10,81	5,59
24.06.2006	5,8	5,03	2,7	0,89	30.03.2007	8,21	10,2	14,06	8,8
25.06.2006	5,59	4,85	2,64	0,75	31.03.2007	7,11	7,23	7,77	13,69
26.06.2006	5,41	4,68	2,58	0,65	01.04.2007	6,86	6,26	5,77	11,49
27.06.2006	5,22	4,51	2,51	0,56	02.04.2007	6,96	6,26	6,48	8,48
28.06.2006	5,03	4,34	2,43	0,48	03.04.2007	8,21	8,58	14,19	7,02
29.06.2006	4,85	4,18	2,34	0,41	04.04.2007	8,64	10,44	13,48	11,36
30.06.2006	4,67	4,02	2,26	0,34	05.04.2007	7	6,43	4,45	14,38
01.07.2006	4,5	3,87	2,18	0,28	06.04.2007	7,08	6,34	4,05	9,57
02.07.2006	4,33	3,72	2,1	0,23	07.04.2007	8,01	7,47	12,12	6,26
03.07.2006	4,17	3,58	2,04	0,2	08.04.2007	7,14	6,49	4,99	8,86
04.07.2006	4,01	3,44	1,98	0,17	09.04.2007	6,95	6,22	3,38	6,34
05.07.2006	3,86	3,31	1,93	0,14	10.04.2007	7,49	6,76	9,37	5,03
06.07.2006	3,71	3,18	1,89	0,12	11.04.2007	17,03	27,19	34,67	6,37

07.07.2006	3,56	3,05	1,85	0,11	12.04.2007	8,14	8,08	7,03	33,6
08.07.2006	3,43	2,93	1,81	0,1	13.04.2007	7,84	6,89	3,52	16,89
09.07.2006	3,29	2,82	1,76	0,09	14.04.2007	8,41	7,44	9,45	8,4
10.07.2006	3,17	2,71	1,71	0,08	15.04.2007	7,8	6,81	3,89	7,71
11.07.2006	3,04	2,6	1,67	0,07	16.04.2007	7,75	6,77	4,45	5,05
12.07.2006	2,93	2,5	1,62	0,06	17.04.2007	7,55	6,57	3,32	4,44
13.07.2006	2,81	2,4	1,59	0,05	18.04.2007	9,64	10,92	20,72	3,17
14.07.2006	2,7	2,31	1,56	0,04	19.04.2007	7,69	7,25	6,07	13,01
15.07.2006	2,6	2,22	1,52	0,04	20.04.2007	10,68	14,21	20,33	7,59
16.07.2006	2,5	2,13	1,49	0,04	21.04.2007	8,36	8,43	7,85	18,03
17.07.2006	2,4	2,05	1,46	0,03	22.04.2007	8,17	7,34	6,26	13,14
18.07.2006	2,3	1,96	1,44	0,03	23.04.2007	8	7,03	4,57	9,04
19.07.2006	2,21	1,89	1,4	0,03	24.04.2007	8,61	7,74	11,13	6,1
20.07.2006	2,13	1,81	1,37	0,02	25.04.2007	9,59	10,55	15,73	7,87
21.07.2006	2,04	1,74	1,34	0,02	26.04.2007	9,19	9,87	11,84	12,53
22.07.2006	1,96	1,67	1,32	0,02	27.04.2007	9,96	11,25	15,02	13,41
23.07.2006	1,89	1,61	1,3	0,02	28.04.2007	8,5	7,87	6,26	15,67
24.07.2006	1,81	1,55	1,3	0,02	29.04.2007	8,68	7,8	7,54	10,59
25.07.2006	2,02	1,76	2,87	0,02	30.04.2007	8,48	7,52	6,07	8,38
26.07.2006	2,1	1,86	3,35	0,62	01.05.2007	8,35	7,37	5,72	6,48
27.07.2006	2,47	2,22	5,55	2,25	02.05.2007	8,18	7,21	5,18	5,33
28.07.2006	1,55	1,32	1,69	8,33	03.05.2007	7,95	6,99	4,15	4,45
29.07.2006	1,48	1,26	1,61	0,09	04.05.2007	7,85	6,9	5,08	3,58
30.07.2006	1,43	1,21	1,57	0,05	05.05.2007	7,69	6,74	5,18	3,48
31.07.2006	1,37	1,16	1,53	0,1	06.05.2007	7,4	6,49	3,75	3,18
01.08.2006	1,32	1,12	1,48	0,13	07.05.2007	7,68	6,75	9,33	2,57
02.08.2006	1,26	1,08	1,43	0,15	08.05.2007	7,34	6,53	6,73	4,75
03.08.2006	1,22	1,03	1,39	0,15	09.05.2007	6,86	6,05	3,33	4,37
04.08.2006	1,17	0,99	1,35	0,14	10.05.2007	6,82	6,04	4,34	3,51
05.08.2006	1,12	0,96	1,31	0,12	11.05.2007	6,59	5,84	3,04	3,57
06.08.2006	1,3	1,14	2,65	0,11	12.05.2007	6,58	5,82	4,88	2,53
07.08.2006	1,03	0,88	1,33	0,88	13.05.2007	6,37	5,64	4	2,72
08.08.2006	1	0,85	1,31	0,09	14.05.2007	6,12	5,42	2,9	2,19
09.08.2006	0,99	0,85	1,51	0,09	15.05.2007	6,33	5,59	7,43	1,78

10.08.2006	0,92	0,78	1,27	0,21	16.05.2007	6,43	5,84	8,7	3,54
11.08.2006	0,88	0,75	1,25	0,09	17.05.2007	5,67	5,05	3,1	5,25
12.08.2006	0,85	0,72	1,21	0,09	18.05.2007	10,84	18,26	23,02	3,25
13.08.2006	0,82	0,7	1,17	0,09		5,81	5,37	3,39	22,51
14.08.2006	1,02	0,9	2,35	0,08		7,21	6,95	10,11	11,14
15.08.2006	0,77	0,66	1,29	0,95		7,88	8,75	11,98	10,99
16.08.2006	0,9	0,79	2,1	0,16		6,46	5,89	3,64	12,86
17.08.2006	0,72	0,62	1,39	0,99		7,18	6,62	8,45	8,56
18.08.2006	0,67	0,57	1,22	0,26		7,63	7,6	10,84	8,38
19.08.2006	0,65	0,55	1,22	0,11		8,28	9,5	12,57	9,83
20.08.2006	0,62	0,53	1,18	0,15		6,95	6,51	4,84	13,21
21.08.2006	0,6	0,51	1,14	0,15		8,57	9,22	14,09	9,3
22.08.2006	0,57	0,49	1,11	0,15		16,69	24,81	31,18	13,01
23.08.2006	0,55	0,47	1,09	0,14					34,68
24.08.2006	0,59	0,51	1,44	0,13					
25.08.2006	0,51	0,43	1,1	0,34					
26.08.2006	0,74	0,67	2,18	0,13					
27.08.2006	0,47	0,4	1,14	1,34					
28.08.2006	0,48	0,41	1,27	0,13					
29.08.2006	0,43	0,37	1,09	0,27					
30.08.2006	0,42	0,36	1,11	0,15					
31.08.2006	0,44	0,38	1,29	0,19					
01.09.2006	0,39	0,33	1,09	0,34					
02.09.2006	0,37	0,32	1,05	0,19					
03.09.2006	0,5	0,45	1,69	0,17					
04.09.2006	0,35	0,3	1,1	0,83					
05.09.2006	0,33	0,28	1,03	0,21					
06.09.2006	0,32	0,27	1,01	0,16					
07.09.2006	0,33	0,28	1,12	0,17					
08.09.2006	0,58	0,53	2,07	0,27					
09.09.2006	0,39	0,35	1,54	1,78					
10.09.2006	0,27	0,23	1,08	1,1					
11.09.2006	0,26	0,22	1,05	0,25					
12.09.2006	0,26	0,22	1,07	0,32					

13.09.2006	0,24	0,2	1,02	0,41
14.09.2006	0,24	0,2	1,05	0,37
15.09.2006	0,52	0,48	2,11	0,4
16.09.2006	0,35	0,32	1,61	2,26
17.09.2006	0,25	0,21	1,29	1,52
18.09.2006	0,25	0,22	1,37	0,95
19.09.2006	0,68	0,65	2,86	1,29
20.09.2006	0,2	0,17	1,27	5,74
21.09.2006	0,18	0,15	1,2	1,97
22.09.2006	0,18	0,16	1,24	2,44
23.09.2006	0,21	0,19	1,43	2,3
24.09.2006	0,16	0,13	1,16	2,23
25.09.2006	0,17	0,15	1,25	1,66
26.09.2006	0,15	0,12	1,12	1,67
27.09.2006	0,14	0,12	1,09	1,23
28.09.2006	0,14	0,12	1,07	1,03
29.09.2006	0,13	0,11	1,06	0,85
30.09.2006	0,69	0,67	3,03	0,74
01.10.2006	0,16	0,14	1,35	5,65
02.10.2006	0,12	0,11	1,19	1,42
03.10.2006	0,11	0,1	1,16	1,76
04.10.2006	0,11	0,1	1,15	1,81
05.10.2006				1,6

9 Ehrenwörtliche Erklärung

Hiermit bestätige ich, dass

- die vorliegende Diplomarbeit selbständig durch den Verfasser und ohne Verwendung anderer als der angegebenen Quellen und Hilfsmittel angefertigt wurde,
- die benutzten Quellen wörtlich oder inhaltlich als solche kenntlich gemacht wurden; und
- diese Arbeit in gleicher oder ähnlicher Form noch keiner Prüfungskommission vorgelegt wurde.

Freiburg, 01.01.2010

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Simon Köhl