Summary

A sustainable agriculture, which provides on the one hand enough yields to satisfy the food demand, and on the other hand minimizes the impacts on ecosystem services such as provision of high water quality, is challenging especially in regions with extreme weather conditions. In this thesis, the current status of the dryland farming agricultural practices under monsoonal conditions, namely plastic mulch ridge cultivation, and its impact on flow processes and nitrate transport was investigated in detail.

A variety of field measurements and tracer experiments in combination with process-based numerical modeling techniques were used to identify the main characteristics of soil hydrological processes such as soil water dynamics, preferential flow, surface runoff, soil erosion and fertilizer nitrate leaching. On hillslopes, we investigated surface and subsurface flow processes in four plastic mulched potato fields (*Solanum tuberosum L.*) using a monitoring network of tensiometers and water content sensors as well as runoff collectors in combination with flow dividers. Since these measurements do not consider preferential flow processes, we additionally carried out tracer experiments using the dye Brilliant Blue FCF. The datasets we obtained of matric potentials, surface runoff and sediment concentrations were used to calibrate the HYDRUS 2/3D and the EROSION 3D model in order to quantify drainage water fluxes, surface runoff and erosion rates of plastic mulched ridge tillage (RT_{pm}) compared to ridge tillage without coverage (RT) and conventional flat tillage (CT).

Plastic mulch affects soil water dynamics dominantly during dry periods and during small rain events, when soil in ridge positions was drier compared to furrow positions caused by the protective function of the plastic coverage and root water uptake in ridges. Hence, pressure head gradients induced lateral flow from furrows to ridges in the topsoil. Under RT the differences in soil moisture were caused only by ridge topography. Thus, horizontal pressure head gradients were weakened compared to RT_{pm}. For CT, pressure head gradients were distinct vertically, which forced the water to flow vertically from the topsoil to the subsoil. Under monsoonal conditions, the differences in soil moisture between ridges and furrows were almost absent since the soil was near saturation or fully saturated. During these events, down slope lateral flow occurred in the coarse textured topsoil due to its higher hydraulic conductivity compared to the subsoil. Based on the dye tracer experiments, we found that plastic mulching caused non-infiltration zones, namely plastic mulched ridges and zones of infiltration in furrows and planting holes, where the tracer infiltrates uniformly into the sandy topsoil matrix. Despite management treatments, we found that lateral funnel flow above the tillage pan was the most prominent feature. In contrast to our expectations, macropore flow via fissures and cracks in deeper soil horizons was not detected. The field and modeling studies revealed that surface runoff was substantially increased by plastic mulch compared to RT and CT. However, the field topography primarily controlled surface runoff and erosion rates. The concavity of the field led to flow accumulation and high erosion losses in the center of the field, while a convex shape resulted in less soil erosion, because water was channeled in furrows to the field edges.

In a flat terrain, N fate under varying fertilizer rates was investigated in a plastic mulched radish cultivation (*Raphanus sativus*) using a suction lysimeter study in combination with soil water dynamics measurements and a ^{15}N tracer experiment. Arranged in a randomized block design, plots were treated with fertilizer rates of 50, 150, 250 and 350 kg NO_3^- ha^{-1}. Leaching was found to be the main prominent pathway for NO_3^- especially during the early season, when crops had not yet emerged. Furthermore, the biomass production did not significantly differ between fertilizer rates of 150 to 350 kg ha^{-1} . Hence, we recommend the lowest NO_3^- fertilizer application of 150 kg ha^{-1} in combination with a better fertilizer placement and split applications. Based on the obtained datasets of nitrate concentrations and matric potentials we subsequently calibrated a water flow and solute transport model using the numerical code HydroGeoSphere coupled with

ParallelPEST. We simulated whether the given recommendations on fertilizer best management practices (FBMPs), such as a better placement and split application, decreased NO_3^- leaching amounts. Compared to RT under conventional fertilization in ridges and furrows, the simulations showed that NO_3^- leaching can be considerably reduced up to 82% by combining RT_{pm}, fertilizer placement only in ridges and split applications with a total fertilizer NO_3^- amount of 150 kg ha^{-1}.

Based on these findings, the impact of plastic mulched ridge cultivation on flow and transport processes has to be evaluated differently depending on terrain complexity. In a flat terrain, where surface runoff processes are absent or minimal and precipitation contributes entirely to groundwater recharge, RT_{pm} has several advantages. Beside functions such as weed control, and earlier plant emergence due to higher temperatures, plastic mulching decreases drainage water and NO_3^- leaching during the growing season. Thus, RT_{pm} enhances nutrient retention below the plastic coverage and reduces the risk of groundwater contamination by highly mobile agrochemical substances. In a sloped terrain, where precipitation contributes substantially to surface runoff, plastic mulching even increases runoff processes, inducing a high risk of flooding, soil erosion and surface leaching of agrochemicals into aquatic systems.

This thesis provides several recommendations, aiming to minimize environmental impacts and concurrently to decrease costs of fertilizer and herbicide inputs. In order to reduce surface runoff and soil erosion at fields on hillslopes, we suggest applying perforated plastic mulch instead of impermeable plastic mulch and a ridge configuration following contours of the field. Furthermore, we recommend omitting application of herbicides to furrows in order to allow weed growth. This would lead to a higher surface roughness in furrows, which in turn slows down runoff processes. These suggestions would obviously increase infiltration, thus, the subsurface flow processes automatically become more important. However, preferential flow in macropores to deeper soil layers was found to be absent, which is a good indicator for minor groundwater contamination risk. Since funnel flow above the tillage pan was found to be the most important preferential flow path, we propose to protect the river network from contaminant discharge via subsurface lateral flow by the establishment of riparian buffer zones. This would also help to reduce the discharge of sediments, fertilizers and agrochemicals via surface runoff into the streams. Finally, fertilizer best management practices (FBMPs) such as fertilizer placement only in ridges and split applications as well as the combination of both, were found to decrease nitrate leaching considerably. Hence, we suggest applying FBMPs in combination with impermeable plastic mulch in flat terrain, while on hillslopes FBMPs should be applied in combination with perforated plastic mulch. The recommendations imply that the risk of leaching becomes more important after harvest when the plastic mulched ridges are removed and the remaining nitrate is prone to leaching. Therefore, we recommend to cultivate cover crops after harvest to improve N fixation, to reduce NO_3^- leaching, to increase the organic carbon content of the soils as well as to prevent soil erosion in autumn.