Schmidt G. et al., 2010. regional adaptation on climate change – supporting land management decisions in the Central German dry region by geoecological research.
The Problems of Landscape Ecology, Vol. XXVIII. 111–122.

Regional adaptation to climate change – supporting land management decisions in the Central German dry region by geoecological research

Gerd Schmidt[1], Manfred Frühauf[2], Soeren Dammann[3]

Martin Luther University Halle-Wittenberg, Institute of Geosciences
Von-Seckendorff-Platz 4, 06120 Halle, Germany
e-mail: [1] gerd.schmidt@geo.uni-halle.de, [2] manfred.fruehauf@geo.uni-halle.de,
[3] soeren.dammann@geo.uni-halle.de

Abstract: Land use, Land management and land use planning in Germany are faced with big challenges in the future. These are caused by climate change on one side and by the regulations of European community. Agriculture has to find out sustainable agricultural management strategies to adapt on changing natural and societal conditions. One of the most preferred methods is the application of conservation tillage. This is caused by the positive effects of minimized tillage operations on the physical properties of the soils. Conservation tillage tends to result in higher infiltration capacity and improved soil water availability for plant growth. But some questions arise from the hydrological point of view. Many of these are related to the water capacity of soils, increasing Evapotranspiration and decreasing runoff generation. The Eastern Foothills of the Harz Mountains belongs to the driest regions of Germany. Special focus has to be taken here on water balance. Climate change projections show that the situation in the dry region of Central Germany will be more difficult in future because the inner annual precipitation dynamic changes to more snow in winter and less rain in summer. With our recent field investigations we i) generate data sets to analyse the effects of conservation tillage on landscape water balance runoff and water quality and ii) involve the regional stakeholders into our research at specially developed and managed test sites. Long term data analyses show decreasing annual average discharges in the main streams of the area on one side. On the other side we recognise that the soil water contents increase under conservation tillage. Soils provide more water for plant nutrition and Evapotranspiration. In that has to be seen potential challenges of further adaptation to climate change and land use optimisation regarding to the targets of the WFD.

Kew words: *adaptation on climate change, minimum tillage, regional water balance, soil water, discharge*

Introduction

Land use, land management and land use planning in Germany are faced with big challenges in the future. These are caused by climate change on one side and by the regulations of European community in different sectors on the other side. Especially the agricultural sector is affected by this situation, because its production system depends on natural frame conditions and agriculture affects in different way on natural resources like soil and water. Hence agriculture underlies many environmental regulations like

- 2000/60/EC – framework for Community action in the field of water policy,
- 92/43/EEC – conservation of natural habitats
- Common Agricultural Policy (CAP) – Cross Compliance
- Federal Soil Protection Act (BBodSchG)

One general demand posted in these regulations is the application of sustainable agricultural management practices – especially methods of conservation tillage. This is caused by the positive effects of minimized tillage operations on the physical properties of the soils (Halvorsen et al 2002, Mc Conkey et al 2003, Lafond & Derksen 1996, Lal & Kimble 1997). Conservation tillage tends to result in higher infiltration capacity and improved soil water availability for plant growth (Batjes 1999, Benites et al 1999). Higher infiltration capacity of soils decreases the liability to soil erosion. Therewith a reduction of sediment and nutrient input into river system can be expected. The sufficient availability of soil water for plant growth is one of the main agricultural problems to be solved in dry regions (Mc Conkey et al 2003, Lafond & Derksen 1996, Lal & Kimble 1997). In consideration to that the implementation of conservation tillage is also an adequate agricultural adaptation strategy on climate change in dry regions. It seems like science, engineering and farmers had found the universal answer on the problems of climate change, water- and soil protection, the community is faced with.

Focussing on that arise some questions from the hydrological point of view. These are related mostly to infiltration, water capacity of soils, Evapotranspiration and runoff generation. The more rain water infiltrates into soil and is kept as retained water, the more water is available for plant nutrition and Evapotranspiration, the less water remains for natural replenishment and runoff in river systems. This leads us to the main question: Is there a critical extend of conservation tillage in river basins in regions with stressed water balance? Main goal of our research is to find out appropriate agricultural management practices that allow both economical and ecological sustainability under the conditions of climate change. With our recent field investigations we generate data sets to analyse the effects of conservation tillage on landscape water balance runoff and water quality in the Central German Dry Region. This extensive work wouldn't be possible without the cooperation with regional stakeholders. The paper includes our investigation strategy, data collection methods and the way we involve stakeholder in our work.

Investigation Area

The Eastern Foothills of the Harz Mountains (figure 1) belongs to the driest regions of Germany with less than 500 mm annual precipitation. Special focus has to be taken on the water balance which is negative in the long term average. Years with surplus alter with deficit years. This situation induces a very high runoff dynamic with long periods of low flow and very short extreme runoff events (Schmidt & Frühauf 2001).

The investigation area covers a 500 km² river catchment. It is intensively used by agriculture based on the specific climate conditions and the fertile soils. One of the most former, current and future problems is the availability of water for plant growth for agriculture on one side and for the generation of discharge in the small river systems on the other side.

Climate change projections show that the situation in the dry region of Central Germany will be more difficult in future. The total amount of yearly rainfall will not change significantly but the inner annual precipitation dynamic changes to more snow in winter and less rain in summer. Another prediction for that region is that summer precipitation focuses increasingly on single storm events. This development is already analyzed by FABIG (2007) based on regional weather data of the last century (figure 2). Another

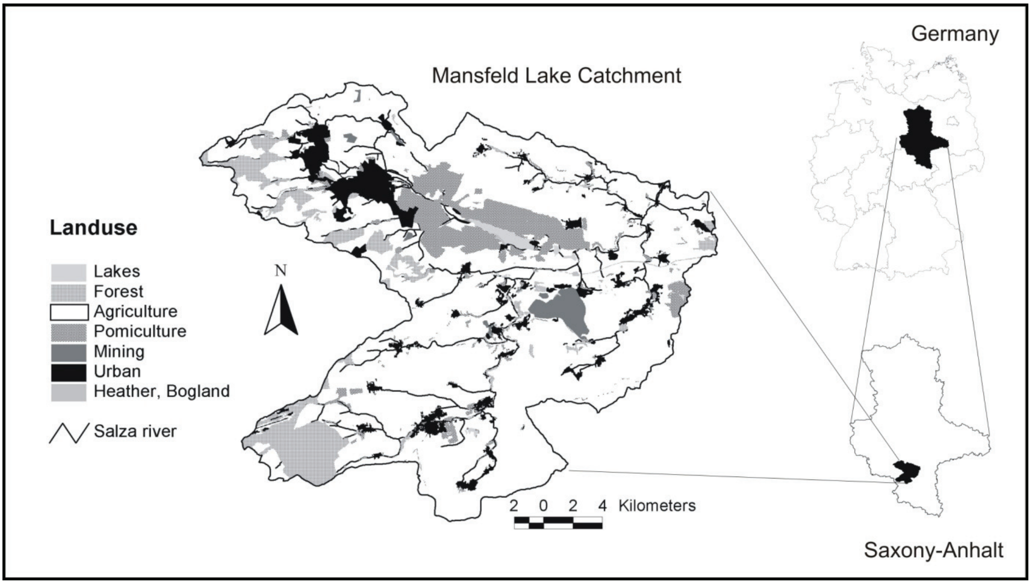

Fig. 1. River Salza catchment as part of the Eastern foothills of Harz Mountains

appearance of climate change in that region are increasing spring and early summer droughts with rainless periods up to 40 days, what was very unusual in the early 20th century. These developments at the regional scale show that climate change is the problem we are not only faced with in the future. It already happens and we have to adapt on it now.

The regional climate occurrences furthermore will lead to i) less infiltration, ii) increasing surface run off generation, iii) increasing sediment and nutrient input in river systems, iv) more flood events and v) less

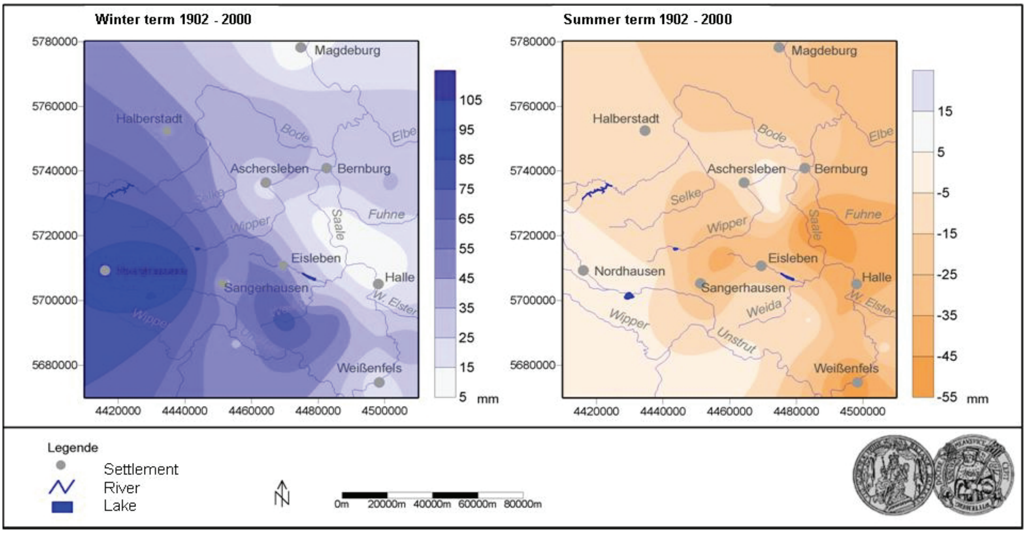

Fig. 2. Precipitation changes in the Central German Dry Region in the 20th century (FABIG 2007)

water availability for plant nutrition. That affects both agricultural production and natural resources. Long term analysis of the hydrographs of the three main gauges in the Salza catchment already shows slightly decreasing average discharge during the last 40 years (figure 3). Two gauges are situated at the outlet of the sub basins of the Salza catchment Böse Sieben (Unterrißdorf) and Querne-Weida (Stedten). The third gauge (Zappendorf) represents the outlet of the whole Salza catchment just upstream of its inflow into the Saale river.

The trends show that the hydrological situation became more stressed in the area. To meet the challenges of climate change an application of sustainable adaptation measures is required. This is only possible by joint activities of scientists, policy makers and regional stakeholders

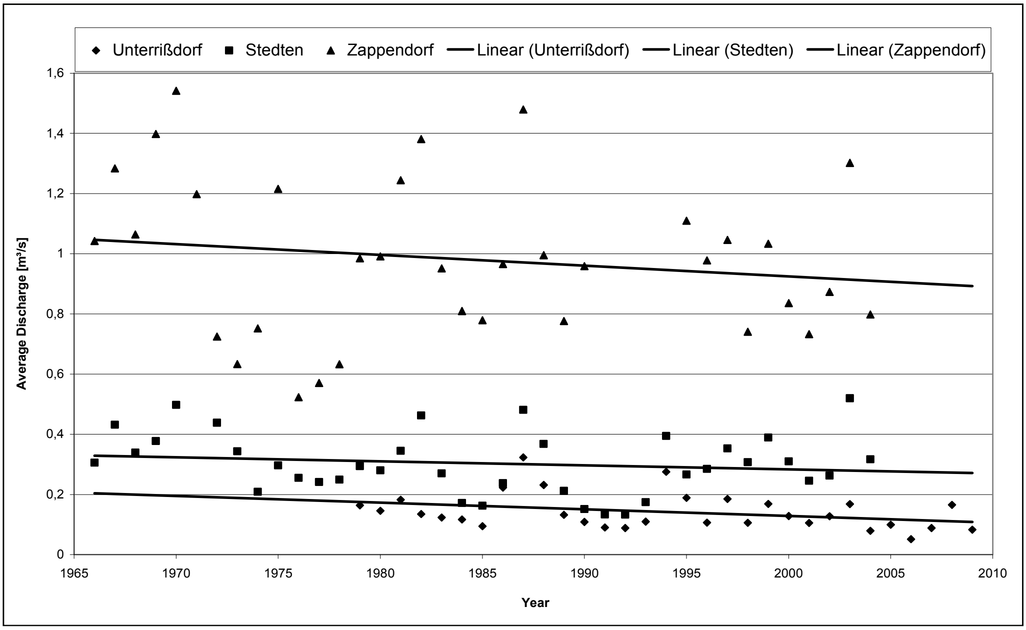

Fig. 3. Trends of yearly average flow in the Salza catchment (LHW 2010)

Methods

With our research we analyze the effects of land use strategies and agricultural management practices in rural areas on landscape water balance and water quality in close cooperation with Regional Environmental Agencies, Farmers and Agricultural Machinery Manufacturers. The application of conservation tillage is one of the regional adaptation strategies on climate change (AGKW-LSA 2010). It is also recommended as measure to protect the water bodies from non point nutrient and sediment input.

Based on different research projects we try to generate basic knowledge to develop regional adaptation strategies on climate change. As well we have the requirement of the European Water framework directive in view. This includes the i) investigation of effects of agricultural management practices on soil water balance and soil erosion ii) investigations on nutrient and sediment input into river systems and iii) long term analyses of climate and land use effects on hydrographs. In addition to that methodical questions of the application of adapted monitoring strategies play an important role. All these research activities are carried out in collaboration with Regional Environmental Agencies, Water and Flood Management Department, Farmers and Agricultural Machinery Manufacturers.

Recently we work in two projects about the impacts of agricultural management on soil water balance and soil erosion. For this reason we run an experimental field at the intensive agricultural used Querfurt Plains to record the on site situation. At this side (see fig 4) we test in close cooperation with AMAZONE Agricultural Machinery Company the effects of cultivation methods on physical properties of soils. Tillage operations, crop rotations, fertilisation and pest management are discussed and agreed with the farmer. The test site is managed with 5 tillage operations of different intensity starting with conventional tillage (plough) and ending with no till (see left side of the figure). Soil physics and soil water content is recorded biweekly manually at 5 depths. At the extreme plots (plough, no till) we record soil water content and tension traction permanently at 3 depths (see right side of the figure). Volumetric soil water content is measured with FDR technique and tension traction by pf-meters in sub daily time steps.

Fig. 4. Experimental field at the Querfurt Plains

As well we map plant parameters at the growing season, yield and also possible soil erosion indicators. All collected data are presented to the farmer and the AMAZONE Company. All project partners discuss the results together and plan the activities for the next season. This leads in our opinion to high transparency and acceptance by the farmers.

The off site effects were measured at the main tributaries of the Salza catchment (figure 5). This research focuses on discharge dynamics, sediment and nutrient load. Long term discharge data are provided by the Regional Water Authority. With different sampling strategies we take random and composite samples and estimate average and event based nutrient loads of the small rivers.

Load estimations are carried out regarding to the sampling strategy (Gurpal et al. 2008, King et al. 2005, Schmidt & Frühauf 2001, Webb et al. 1997). The results were correlated with water content and runoff generation at the test sites on one side. On the other side we focus our research to low flow periods. These are important to asses the effects of climate and land use change on aquatic biocenosis.

Fig. 5. Gauge Unterrißdorf at the Böse Sieben brook

Stakeholder involvement began at a very early stage. Our research is carried out at the property of a farmer. So we have explained him our research idea, the methodical concept and the practical needs. Tillage operations, crop rotations, fertilisation and pest management are discussed and agreed with the farmer. All results were presented and discussed at regular meetings.

The climate change projections for the Central German Dry Region show that the development is directed to a continental steppe climate. Hence we established our research also in some regions of the Eurasian Steppe Zone with test sites in Ukraine, Bashkir Republic and the south Siberian KULUND Steppe (see figure 6). Our research focuses beside the analyses of impacts of tillage operations on soil physics and soil water balance also on the development of humus stock in steppe soils. Regarding climate change agricultural managed steppe soils have a great potential of carbon sequestration (Houghton 1995, Frühauf & Meinel 2004, Frühauf & Meinel 2006, Fan et al. 2007). Soil Carbon is one of the main steering factors of the soil water balance.

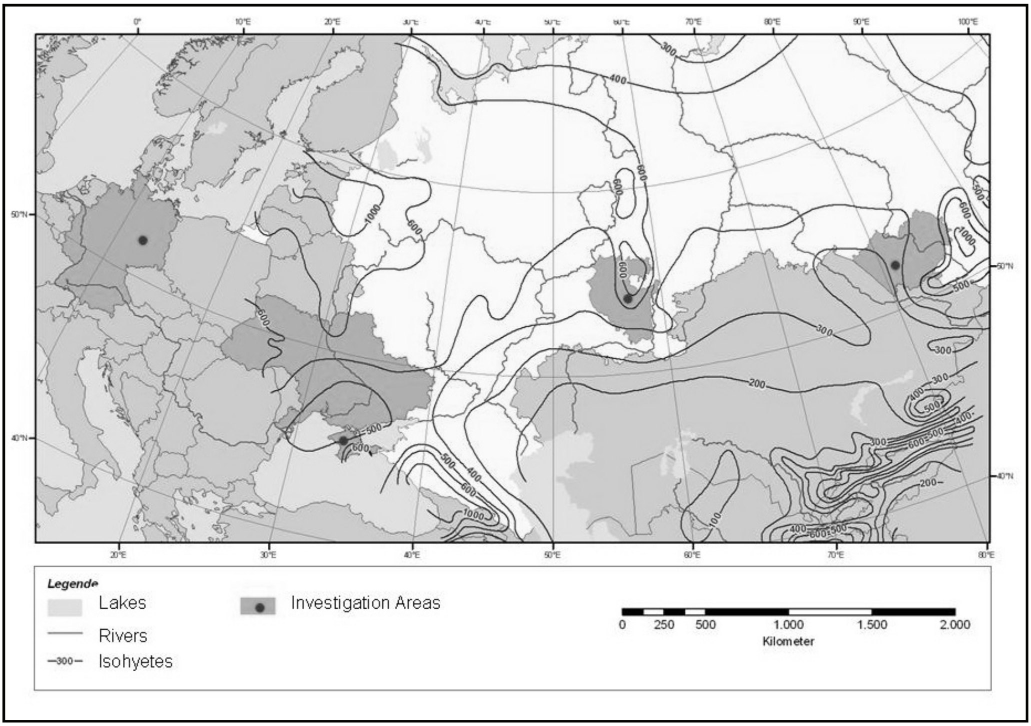

Fig. 6. Investigation areas at the Eurasian Steppe Zone

Results

While the projects are still running final results couldn't shown yet. But the results show already at the recent stage interesting developments in soil water content as well as in discharge and sediment load of the small rivers.

The research shows increasing average soil water content under not till based on the biweekly measurements (figure 7). Hence results higher water availability for plant nutrition and based on this higher yields under no till. Such effects are also shown by the investigations of LAFOND & DERKSEN (1996) at the Canadian Steppes.

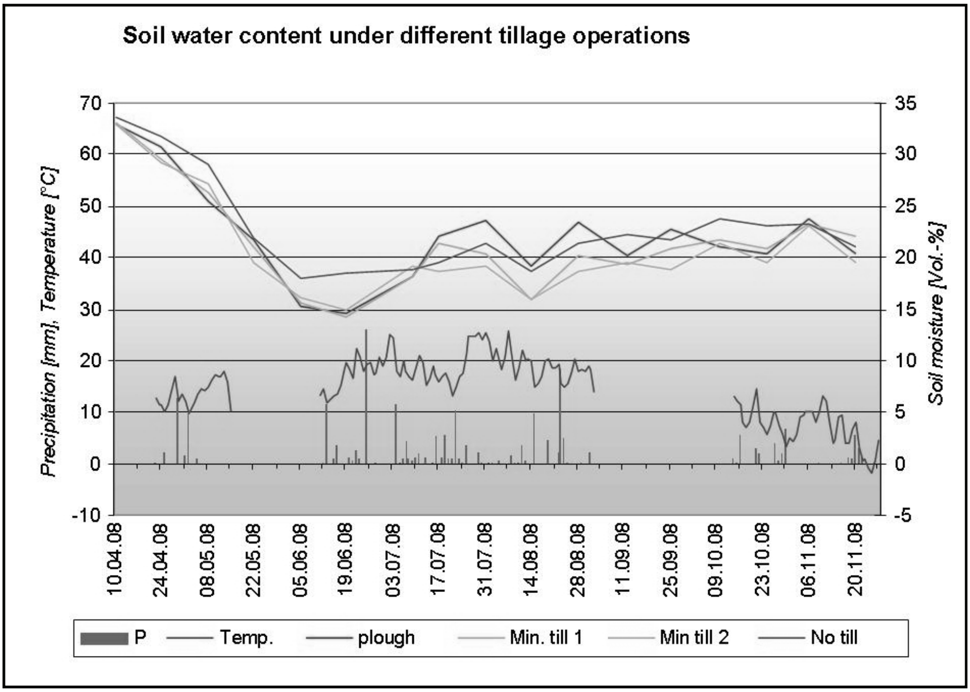

Fig. 7. Soil moisture under different tillage operations at test site Querfurt Plains

The analysis of data of permanent soil water content measurements with high resolution at the plots with no till and conventional till shows a differentiated picture in function of depth. While the soil water content at the top soil of the ploughed plot is much higher than at the no till, the deeper layers show the opposite situation. Figure 8 shows the soil water content by time over two years at the top soil layer. We expected always higher soil water content under no till. The situation shown in the figure below could be explained by soil compaction as effect of ploughing. The ploughing reaches a depth of 30 to 35 cm. This is the soil compaction layer that avoids or reduces infiltration to the deeper soil layers. Infiltration water accumulates at the top layer, the pore volume will be filled up quick and the risk of runoff generation and overland flow is very high. The infiltration capacity of the soil under no till is much higher caused by preferential flow in macro pores. Water has better opportunities to percolate into deeper soil layers. The risk of runoff generation is much lower.

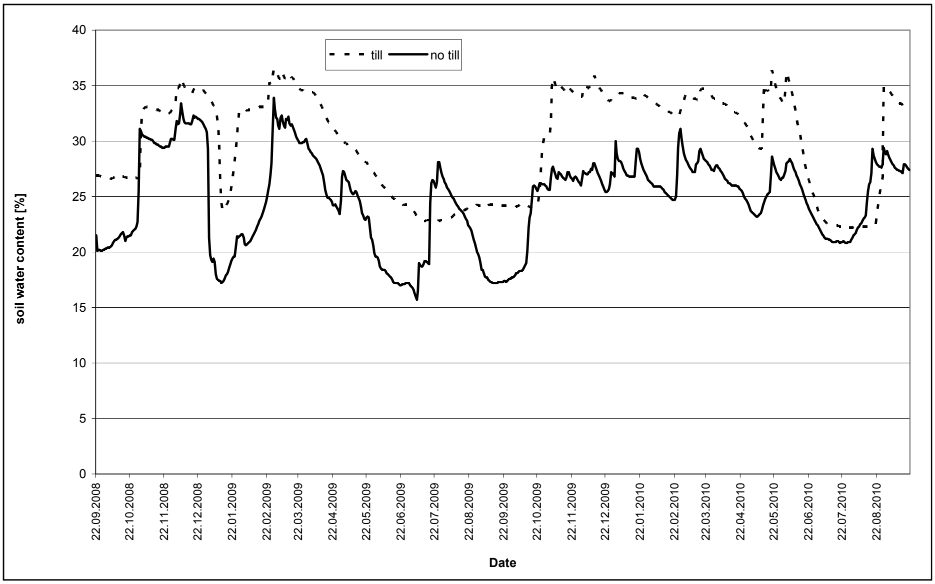

Fig. 8. Soil water content of top soil at Querfurt plains test site

Setting the focus on deeper soil layers soil water content under different tillage operations is reversing (figure 9). During time the gap between the two plots increases remarkably as well.

The reason for that again could be seen in the much better pore structure of the soil under no till. This soil is able to infiltrate a bigger amount of water by time than the one under ploughing. The peaks in the

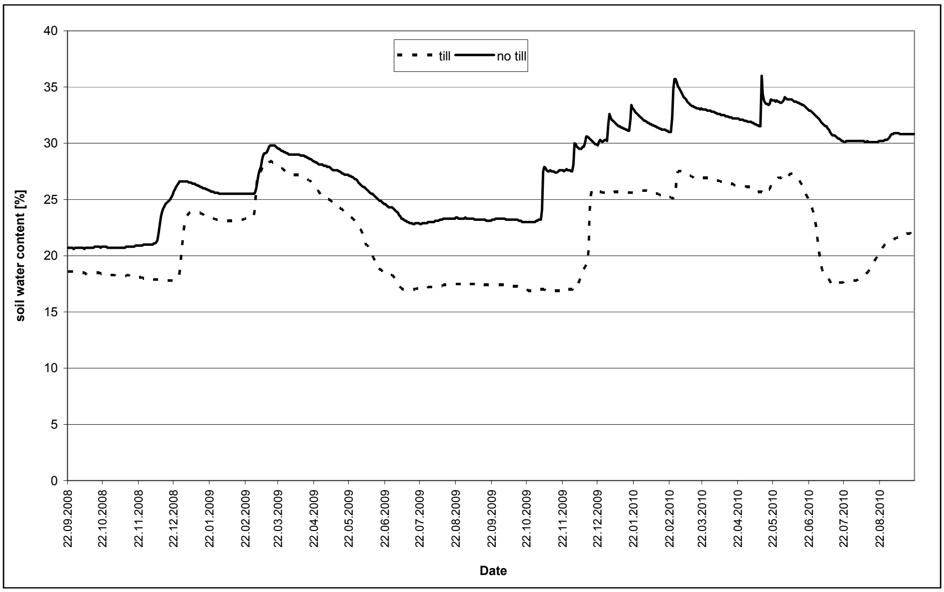

Fig. 9. Soil water Content at 90 cm depth at Querfurt Plains test site

graph of the no till plot show as well the reaction of soil water content on rainfall events. We couldn't find these at the ploughed one. The two smaller peaks show the alleviated and delayed reaction on rainfall. Interesting is the fact, that the soil water content decreases during crop maturity under ploughing to the level of the previous year. Under no till the water content kept staying on a much higher level. Focussing on these results no till measures improve the soil water capacity and help to provide more water to plant nutrition. No till measures are applied in the region since the middle of the 90ies with increasing acreage. The effects of this change in management on landscape water balance are not investigated up to now.

The discharge analysis at the gauge Unterrißdorf at Boese Sieben brook shows besides the decreasing of average flow also increasing low flow durations (figure 10), decreasing of yearly low flow and increasing discharge magnitudes (figure 11).

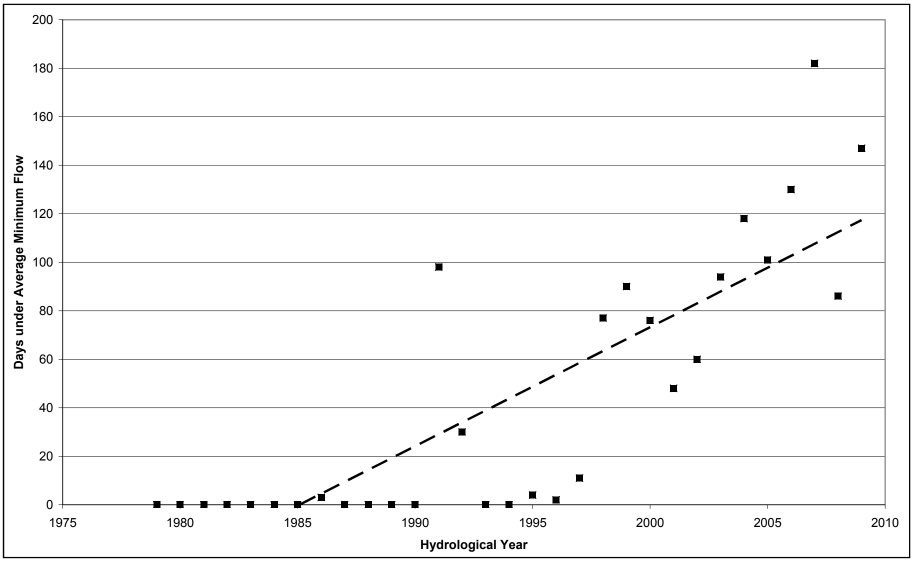

Fig. 10. Duration of low flow periods of Böse Sieben brook

Böse Sieben brook was fed in the eighties by a huge amount of wastewater from the regional settlements. This is the reason why we did not register low flow days. The waste water input did increase the Discharge over average low flow artificially. After the German reunification big efforts was made to transfer the waste water out of the catchment. This reduces the discharge step by step to a more natural level. Beginning with the 90ies the first low flow days in the area could be counted. The new waste water scheme was already finished in 2004. But the number of days with low flow is still increasing.

The changes in the hydrological system find their expression also in the hydrological magnitude (figure 11). The relation between Peak flow and low flow also increases slightly over the last 40 years.

Up to now the reasons for these changes in the hydrological system of the area are not known yet. Further investigations will focus on the possible steering factors of this development. The role of climate change, land use and land use adaptation in this connection is to clarify.

With respect to the implementation of our research results we follow a versatile strategy. One activity is the close cooperation with farmers and manufacturers, where we plan and organise research work at the field on one side and present the results on the other. In addition to that we organise in close cooperation

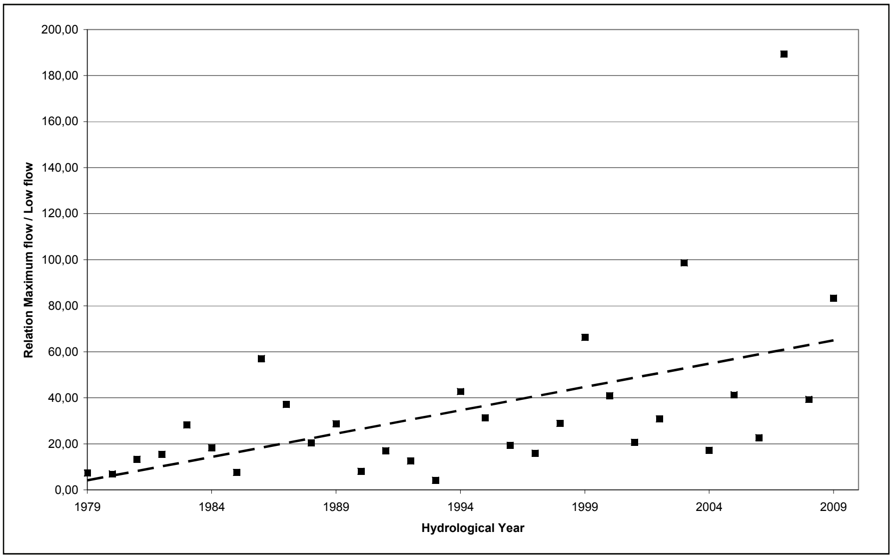

Fig. 11. Yearly discharge magnitude of Böse Sieben brook

with regional authorities and institution information workshops with focus on climate change, adaptation strategies and land us impacts on landscape balance. One of the recent results of these efforts is the presentation of a practical handbook about soil erosion in Saxony-Anhalt, which especially focuses on questions of soil and water protection (Helbig, Möller & Schmidt 2010).

Conclusions

The adaptation on climate change is one of the big future challenges in agriculture of the Central German Dry region. Agriculture is here limited by the stressed water balance and further changes in the inner annual water availability for plant nutrition. Agricultural management adaptation focuses on the improvement of physical soil properties and soil water capacity to secure water supply for plant growth. The effects of this strategy on landscape water balance are still not sufficiently investigated and discussed. Our research focuses on the soil water balance and the effects of increasing water availability for plant nutrition on evapotranspiration, runoff generation and river discharge. Decreasing discharges are counterproductive to the efforts that have to be made to meet the targets of the European Water Framework Directive. In that could be seen challenges of further adaptation to climate change and land use optimisation regarding to the targets of the WFD.

Acknowledgements

The presented research results are generated in projects under finance of AMAZONE Company, the Department of Water Management and Flood Protection and the Department of Agriculture, Forestry and Gardening in Saxony-Anhalt. Special Thanks we send to the Farmers Agricultural Company Darmstadt and Agricultural Cooperative Querfurt that allows us the intensive field work on their property.

References

AGKW-LSA – Arbeitsgruppe Klimawandel des Landes Sachsen-Anhalt (2010): Strategie des Landes Sachsen-Anhalt zur Anpassung an den Klimawandel und dazu gehörender Aktionsplan, Magdeburg.

Batjes, N.H. (1999): Management options for reducing CO_2-concentrations in the atmosphere by increasing carbon sequestration in the soil. NRP Report no.: 410 200 031, International Soil Reference and Information Center (ISRIC), Technical Paper 30, Wageningen, The Netherlands. 110 pp.

Benites, J., Friedrich, T. & A. Brot 1999. Conservation Tillage: An Entry Point for Sustainable Agriculture in Eurasian Countries. In: Karabayev, M., Satybeldin, A, Benites, J., Friedrich, T., Pala, M. & T. Payne (Edts.): Conservation Tillage: A Viable Option for Sustainable Agriculture in Eurasia, Proceedings of an International Workshop, 19–24 September 1999, Astana, Kazakhstan, 27–43.

Fabig, I. 2007. Die Niederschlags- und Starkregenentwicklung der letzten 100 Jahre im Mitteldeutschen Trockengebiet als Indikatoren möglicher Klimaänderungen, Dissertation, Martin-Luther-Universität Halle-Wittenberg, unveröffentlicht.

Fan, J.; Zhong, H., Harris, W., Yu, G., Wang, S., Hu, Z. & Yue, Y. 2007. Carbon storage in the grasslands of China based on field measurements of above- and belowground biomass. In: Climate Change 86: 375–396.

Frühauf, M. und T. Meinel 2004. Ecological consequences of steppe conversion to arable land in west Siberia. In: Europa Regional, 12. Jg. 01/04, Leipzig.

Frühauf, M. und T. Meinel 2006. Desertification in the agricultural used dry steppes in central Asia. Proceedings of the International Conference Soil and Desertification – Integrated Research for the Sustainable Management of Soils in Drylands 5–6 May, Hamburg, Germany Organised by Desert Net Germany and AK BoGeo http://www.desertnet.de/proceedings/start

Gurpal S.T., Harmel, R.D., Haggard B.E. & G. Schmidt 2008. Evaluation of Regression Methodology with Low-Frequency Water Quality Sampling to Estimate Constituent Loads for Ephemeral Watersheds in Texas. In: Journal of Environmental Quality, Volume 37, 1847–1854.

Halvorson, A.D. et al. 2002. Tillage system and crop rotation effects on dryland crop yields and soil carbon in the Central great plains. Agron. J. 94: 1429–1436.

Helbig, H. Möller, M., & G. Schmidt (Hrsg.) 2010. Bodenerosion durch Wasser in Sachsen-Anhalt. BVB-Materialien, Band 15, Berlin, 106.

Helbig, H., Möller, M. & G. Schmidt (Hrsg.) 2010. Bodenerosion durch Wasser in Sachsen Anhalt.

Houghton, R.A. (1995): Changes in the storage of terrestrial carbon since 1850. – Lal, R., Kimble, J., Levine, E. & Stewart, B.A. (eds.): Soils and Global Change. Boca Raton: CRC Press: 45–65.

King K.W., Harmel R.D. & N.R. Fausey 2005. Development and sensitivity of a method to select time- and flow-paced storm event sampling intervals for headwater streams. In: Journal of Soil and Water Conservation. Volume 60. Number 6. 323–331.

Lafond, G.P. and D.A. Derksen 1996. The long term potential of Conservation Tillage on the Canadian Prairies. In: Can. J. Plant Pathology 18: 151–158.

Lal, R. & Kimble, J.M. 1997. Conservation tillage for carbon sequestration. – Nutrient Cycling in Agroecosystems 49: 243–253.

McConkey, B.G., Liang, B.C., Campbell, C.A., Curtin, D., Moulin, A., Brandt, S.A. & Lafond, G.P. 2003. Crop Rotation and Tillage Impact on Carbon Sequestration in Canadian Prairie Soils. – Soil & Tillage Research 74: 81–90.

Schmidt, G. & M. Fruehauf 2001. Drainage Pattern and substance transport dynamics of moving waters in the catchment area of the impending Salziger Lake (Mansfelder Land – Germany), In: The operation of geoecosystems in various morphoclimatic conditions – New results of geoecological research; Adam Mickiewicz University Poznan, Conference Proceedings, Adam Mickiewic University Poznan, 477–490.

Webb, B.W., Phillips J.M., Walling D.E., Littlewood I.G., Watts C.D. & G.J.L. Leeks 1997. Load estimation methodologies for British rivers and their relevance to the LOIS RACS(R) programme.-In: The Science of total Environment, 194/195, 379–389.

Zentner, R.P., Lafond, G.P., Derksen, D.A., Nagy, C.N., Wall, D.D. and May W.E. 2004. Effects of tillage method and crop rotations on non-renewable energy use efficiency for a thin Black Chernozem in the Canadian Prairies. Soil & Tillage Res. 77: 125–136.