Górnictwo i Geoinżynieria • Rok 35 • Zeszyt 3 • 2011

*Dirk Freese**, *Christian Böhm**, *Ansgar Quinkenstein**

THE CONTRIBUTION OF AGROFORESTRY SYSTEMS TO LAND RECLAMATION

1. Recultivation of open-cast mining areas in Lusatia

Open-cast mining activities induced landscape degradation and can be considered as one of the most severe anthropogenic disturbance of the terrestrial and aquatic ecosystems.

The conveyer belt technology in the Lusatian lignite mining district enabled large scale excavation of lignite seams since the 1920s. The annual lignite mining amounted 195 million tons from 17 mines in the late 1980s and decreased to 60 million tons after the German unification [6]. Presently, five open-cast mines are active in the Lusatian district and are negotiated to operate until 2030 to 2040.

More than 80.000 ha are affected by open-cast lignite-mining activities in Lusatia [6]. The conveyer belt technology mix the upper quaternary and lower tertiary sediments inducing the oxidation of pyrite from the tertiary marine-brackish sediments and leading to strong acidification and high salinity [7]. The chemical processes in post-mining regions differed particularly in the initial phase when compared to the pre-mining situation and the site specific geochemical composition control largely the element fluxes of the developing systems. In addition, geogenic and lignite derived carbon in these sandy nutrient poor soils may play a significant role in the water and nutrient supply of the developing ecosystems. These conditions have a large influence on both above and below ground biomass development and humus accumulation being important components of the ecosystem nutrient cycle.

Since forest area was dominant before mining at 60% (Fig. 1), the recultivated area has to be re-forested which is done with different tree species aiming on an establishment of mixed stands. The percentage of agricultural areas decrease from 31 to 22% but the best quality subtrates (loamy texture, high pH) are choosen for dumping to realize a fertile and productive soil development during the post-mining period. Nevertheless, re-cultivated sites developed on substrates that are not equivalent to the ´undisturbed´ landscape. Therefore much effort has to be spend to increase the efficiency of recultivation and reclamation.

* Chair of Soil Protection and Recultivation, Brandenburg University of Technology, Cottbus, Germany

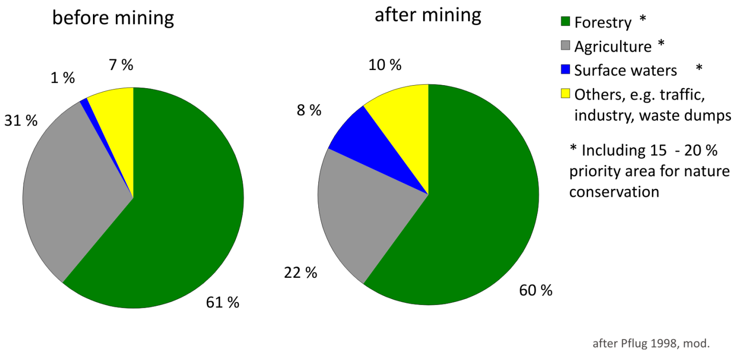

Fig. 1. Distribution of land use sectors before and after mining in Lusatia (modified from [13])

2. Agroforestry

The growing human population, in combination with the increasing costs for fossil energy, will enhance pressure on the land [16]. On intensively managed land, increased biomass production could cause additional pressure on ecological functions of agro-ecosystems, and on soil and water resources (EEA Report No. 7/2006). Innovative solutions are required that ensure higher productivity without further damaging natural resources and allow adaptation to the changing climatic conditions. Combining trees and crops in agroforestry systems improves the efficiency of utilisation of resources (light, water, nutrients) and thus leads to an overall higher biomass production [11]. Simultaneously, soil erosion and nitrate leaching are reduced and landscape biodiversity is increased [12]. Agroforestry has been shown to be an innovative land use system for Europe that can combine the production of food and wood (bioenergy, timber) with ecological functions on the same field (EU-funded SAFE project (2001–2005; http://www.montpellier/inra.fr/safe/). Moreover, in marginal regions and on degraded lands, agroforestry constitutes an alternative to land abandonment and/or to deliberate afforestation, leads to diversification of land use and offers new income possibilities.

The definition is given by the World Agroforestry Centre (Kenia):

— „Agroforestry is a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels".

Agroforestry can be technically defined as all land use systems and practices, that combine woody perennial crops (trees, bushes) with herbaceous plants (agricultural crops, pasture) and/or productive livestock through spacial arrangements, temporal rotation or both. Rigueiro-Rodríguez et al. [14] define it as a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. Agroforestry has the ability to provide short-term economic benefits while the farmer waits for traditional longer-term forestry products.

Benefits that agroforestry provides include the following: protecting soil resources, improving air and water quality, enhancing wildlife habitat, and structuring the landscape. In addition, agroforestry offers farmers an array of ecological and economic opportunities. Table 1 point out some of the ecological benefits of implementing agroforestry.

Agroforestry encompasses a very large and diverse set of practices ranging from croplands, in which a minimal tree component has been added, to complex forest production that has been integrated into an existing forest structure. A general classification developed by Nair (1985) puts the many agroforestry practices existing worldwide into three major types based on the combination of the components:

— Agrisilvicultural: crops and woody plants;
— Silvopastoral: pasture and/or animals and woody plants;
— Agrosilvopastoral: crops, pasture and/or animals and woody plants.

TABLE 1

Examples of practices within agroforestry which have potential to help stabilize greenhouse gas (GHG) emissions and sequester or conserve C in the terrestrial biosphere [9]

Agroforestry System	Reduce emissions	Conserve / sequester C or N
Silvopastoral		
Remove marginal land from agronomic production (conserve soil C)	*	*
Retain organic matter on site (conserve C)	–	*
Increase afforestation	*	*
Modify ungulate diets to decrease CH_4 emissions	*	–
Agrosilvicultural		
Conservation tillage and mulching (retain soil C)	–	*
Minimize wind and water erosion (shelterbelts and alley crops)	–	*
Establish perennial multipurpose tree species (sequester CO_2)	–	*
Manage water level, cultivars, fertilization and tillage of paddy	*	*
Reclaim degraded land	–	*
Agrosilvopastoral		
Minimize site disturbance (e.g. tillage or harvesting)	*	*
Augment soil P or K; modify soil pH (stimulate sequestration)	–	*
Recover animal wastes as fuel or organic matter	*	–
Establish legumes, reduce chemical N fertilization	*	*

In the temperate zone, agroforestry systems come increasingly into focus as they offer an approach for the production of fuel wood, thus matching the increasing demand for a self-supply with bio- energy in rural decentralized areas. Studies done in the post-mining area of Lusatia [1, 5] have shown different biomass yields of three fast growing tree species (poplar — Populus spp., willow — Salix viminalis *L*. and black locust — Robinia pseudoacacia *L*). The studies demonstrated that a sustainable supply of bioenergy wood is possible even under marginal conditions of the post-mining area if tree species well adapted to specific climatic and edaphic conditions are selected. The biomass potential of the commonly used fast growing trees species in agroforestry systems (alley cropping) depends especially on the used tree species and the clone, the planting design of the alley cropping system (strip width, planting density), the management (years of rotation, fertilization, pest and weed control), and soil conditions (nutrients, water availability) [15]. The study area is located in the lignite mine Welzow-south about 25 km south of Cottbus. The region has a mean annual rainfall of 560 mm and the average temperature is 9.3°C (1951–2003). The dumped substrates are quaternary loam as well as tertiary sands. The initial content of organic carbon in 0–30 cm soil depth was < 0.3%. Since 1995 several research projects have been carried out to investigate different land use systems mainly focused on fast growing trees in short rotation coppice and agroforestry systems. The alley — cropping system has been planted with black locust in hedgerows and located in between the field alleys. The hedgerows (width 11 m) have drawn across the main wind direction in North-South direction and planted with four double rows of black locust (10 000 trees /ha). The arable strips have a width of 25 m and a typical crop rotation is running.

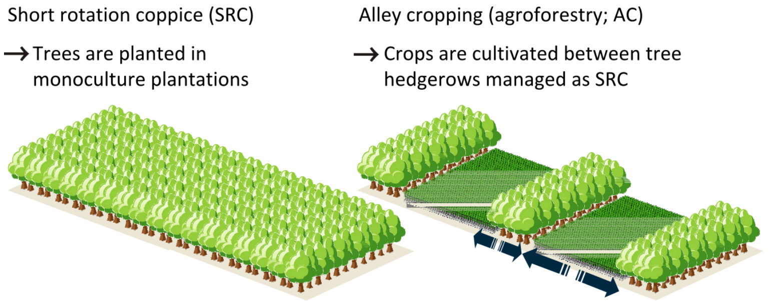

Fig. 2. Short rotation woody biomass production with different land use systems

Alley-cropping is recognized to be highly important in carbon sequestration. By including trees in agricultural production systems, it can increase the mount of carbon stored in lands devoted to agriculture, while still allowing the growing of food crops [8]. Alley-cropping systems are structurally and functionally more complex than either crop or tree monocultures, and therefore are more efficient in resource (nutrients, light and water) capture and utilization, which results in greater C seq. [10]. The hot water extractable carbon (HWC) is defined as the labile fraction of total organic carbon in soil and therefore the deliverable C resource over short term. It has been analysed in the alley cropping system located in the post-mining area of Lusatia [1]. The HWC increased faster in the tree hedgerows of black locust than on the alfalfa field alley. Two years after the establishment of the alley cropping system the HWC contents were significantly ($P < 0.05$) higher than a year previously identified, but the increase was significantly ($P < 0.05$) higher in the tree hedgerows than in the center of the field alley. An interesting feature was that the HWC content increased more in the peripheral areas of the field alley compared to center. This suggests that in alley-cropping systems integrated tree hedgerows have a directly positive impact on the humus accumulation of the surrounding field alleys.

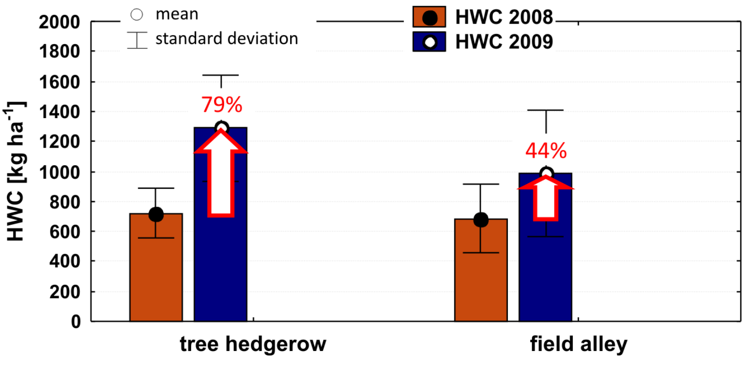

Fig. 3. Hot water extractable carbon (HWC) 1 and 2 year(s) after establishing the alley cropping system (soil depth 0–30 cm; separated into tree hedgerow and field alleys of a AC) [2]

3. Outlook

Recently, main parameters have to be determined identifying relevant ecosystem services and creating an indicator systems to assess the benefits of ecosystem services in agroforestry [3]. In the same context the importance of agroforestry ecosystem services in comparison to conventional agricultural practices has to be analyzed in order to facilitate decision making regarding their sustainable use and land management.

REFERENCE

[1] *Böhm C.*: Erzeugung von Energieholz in Energiewäldern und Agroforstsystemen. Innovationen für Klimaschutz und wirtschaftliche Entwicklung, 2. Rostocker Bioenergieforum, Oktober 2008 in Rostock. Vol. 14

[2] *Böhm C., Quinkenstein A., Freese D. & Hüttl R.F.*: Short rotation woody biomass production as option for the restoration of post-mining areas in Lower Lusatia. XVIIth World Congress of the International Commission of Agricultural and Biosystems Engineering held in Québec-City Canada June 13–17, 2010

[3] *Freese D., Böhm C., Quinkenstein A. und Hüttl R.F.*: Assessment of ecosystem services provided by agroforestry systems in Europe. World Agroforestry Centre (Hrsg.): Book of Abstracts, 2nd World Congress of Agroforestry, Agroforestry — The Future of Global Land Use, Kenia, p. 20–22, 2009

[4] *Freese D., Böhm C., Quinkenstein A., Schneider B.U. & Hüttl R.F.*: Agroforst- flächenschonende Alternative für die Bioenergieproduktion: Feld und Wald auf einem Schlag, Neue Landwirtschaft, 9, 2010

[5] *Grünewald H., Brandt B.K.V., Schneider B.U., Bens O., Kendzia G., Hüttl R.F.*: Agroforestry systems for the production of woody biomass for energy transformation purposes. Ecological engineering 29, 2007

[6] *Hüttl R.F., Klem D. & E. Weber (Hrsg.)*: Rekultivierung von Bergbaufolgelandschaften. Das Beispiel des Lausitzer Braunkohlereviers, Walter de Gruyter Verlag, Berlin 1999

[7] *Hüttl R.F. & E. Weber*: Forest ecosystem development in post-mining landscapes: a case study of the Lusatian, 2001

[8] *Jose S.*: Agroforestry for ecosystem services and environmental benefits: an overview. Agroforest Syst (2009) 76:1–10

[9] *MacDicken K.G. and Vergara N.T. (eds)*: Agroforestry: Classification and Management. Wiley, New York, 1990

[10] *Nair P.K.R., Kumar B.M., Nair V.D.*: Agroforestry as a strategy for carbon sequestration. J Plant Nutr Soil Sci 172:10–23, 2009

[11] *Ong C.K., Black C.R. and Marschall F.M.*: Principles of resource capture and utilization of light and water. In: Ong C.K. and Huxley P. (eds.), Tree-crop interaction. A physiological approach. CAB International, Wallingford, UK 1996

[12] *Palma J.H.N, Graves A.R., Burgess P.J., Keesman K.J., van Keulen H., Mayus M., Reisner Y., Herzog F.*: Methodological approach for the assessment of environmental effects of agroforestry at the landscape scale. Ecological Engineering 29: 450–462, 2007

[13] *Pflug W. (Hrsg.)*: Braunkohletagebau und Rekultivierung: Landschaftsökologie — Folgenutzung — Naturschutz, Springer Verlag, Berlin, Heidelberg 1998

[14] *Rigueiro-Rodríguez A., McAdam J., Mosquera-Losada M.R. (Eds.)*: Agroforestry in Europe. Series: Advances in Agroforestry, Vol. 6, 452 p., 2009

[15] *Quinkenstein A., Wöllecke J., Böhm C., Grünewald H., Freese D., Schneider B.U. & Hüttl R.F.*: Ecological benefits of the alley cropping agroforestry system in sensitive regions of Europe. Environmental Science & Policy, 12, p. 1112–1121, 2009

[16] *Tilman D., Cassman K.G., Matson P.A., Naylor R. & Polasky S.*: Agricultural sustainability and intensive production practices. Nature 418, 671–677, 2002