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Soil erosion control practices in Northeast China: A mini-review

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ABSTRACT

Soil erosion is of great concern in every agricultural region of the world due to its long-term negative effects on soil productivity. Agricultural management strongly affects soil erosion, and thus agricultural sustainability. The control of soil erosion is the top environmental issue, and has been proposed as a bottleneck to the sustainable development of agriculture in Northeast China. This region is the bread basket of China where the fertile and productive Mollisol soil is primarily distributed. The advances in agronomic, biological and engineering practices including several tillage managements, terraces and strip cultivation, and soil amendments are summarized and discussed. Proposed strategies for erosion control in particular urgent government policies to maintain or restore the productivity of severely eroded farmland are emphasized in the context of agricultural sustainability for Northeast China and similar Mollisol regions.

1. Introduction

Environmental protection is among the 10 top concerns of Chinese people, according to online polls conducted by the Xinhua News Agency on 21 February 2011 (www.people.com.cn), and soil erosion is the most important environmental issue. Soil erosion has been a serious hindrance in sustainable development of China (Li et al., 2009; Liu and Yan, 2009). Though the recognition of the detrimental influence of accelerated soil erosion on agricultural societies dates back to Plato and Aristotle (Montgomery, 2007), the awareness of soil erosion as an environmental concern in China can be traced back to 3000 years (Morgan, 2005; Li et al., 2009). Soil and water loss was the very early term equivalent of soil erosion, which was recorded B.C. in China and its antonym at that time was soil and water conservation. It is hard to examine exactly when and how the term soil erosion appeared; however, as a discipline soil erosion has developed since the 1920s, and was initially influenced by American and former Russian scholars (Tang, 2004). In the 1920s, faculty in the Forestry Department from former Jinling University (currently Nanjing University) carried out a soil and water loss survey in certain regions of Shan-xi, Shan-dong, and He-nan Province. They also conducted runoff observations, and thus developed a course addressing soil erosion and control practices for undergraduate students. In 1935, reforestation, grass establishment and vegetation improvement, as well as terrace construction, were strongly recommended to control soil, sand and sediments in the lower reach of the Yellow River. In the 1940s, several research stations focusing on soil and water conservation were established successively in Tianshui, Gan-su Province in 1941, Xi-an of Shaan-xi Province, Lan-zhou of Gan-su Province in 1942, Xi-jiang in Hu-nan Province in 1943, and Nan-jing in 1945, which marked the beginning of long-term observations on soil and water conservation in China. The representative research work in this period was done by Huang et al., who addressed distribution and soil properties in relation to soil erosion in the Loess region (Zheng et al., 2008). Major progress was achieved following 1950s, including characterization of soil and water losses, identification of soil erosion mechanisms, simulation and modeling of soil erosion, dynamic observation and control practice evaluation, establishment of integrated management of small watersheds, erosion classification and regional differentiation, environmental evolution of soil erosion and methodology development for soil erosion research, as well as establishment of a large numbers of research teams. All of these achievements are playing critical roles in discipline definition, policy development and outreach related to soil and water conservation practices (Li et al., 2009). Prof. Bing-wei Huang, Physical Geographer, Prof. Xian-mo Zhu, Soil Scientist and Prof. Ke-li Tang all from the Chinese Academy of Sciences, are pioneer researchers who made substantial contributions to this discipline. Prof. Bao-yuan Liu from Beijing Normal University and Prof. Fen-li Zheng from the Institute of Soil and Water Conservation, Chinese Academy of Sciences are representatives who are actively working in this field.

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The area of unacceptable soil and water loss in China is 3.56 million km^2. The environmental deterioration, particularly associated with soil erosion, has not been effectively controlled in some regions; in fact one could argue that it is ignored as exemplified by the construction of large scale basic facilities for industrialization, urbanization, and regional development without requiring implementation of practices for controlling soil and water losses conservation. Thus, the demand for soil and water conservation technology is more urgent than ever.

Northeast China, the grain production base of China, or the bread basket of China, includes three provinces (Hei-long-jiang, Ji-lin, and Liao-ning) and the eastern part of the Inner Mongolian autonomous region (Liu et al., 2003). In 2009, 17.1% the China's total grain production came from this region, which included 33.5%, 55.7% and 9.6% of corn, soybean, and rice, respectively. Approximately 118 million people live in this region. Grain produced per capita is over 1000 kg annually, and nearly 60% of the grain produced is used to feed about 216 million urban residents annually (Liu et al., 2010). The fertile and productive Mollisols (also called Black soils) in China are distributed primarily in an intergraded area from mountains to plains (Xing et al., 2004), where most of the farmland slopes are less than 7° but slope lengths mainly range from 200 to 1000 m. Nearly 70% of the Mollisols in China are in Hei-long-jiang Province. Because these long slopes in most catchments have been managed for at least 100 years under lower infiltration rates, the combination of high rainfall intensity, freezing and thawing processes, and intensive cultivation has lead to substantial water runoff, soil erosion, and gully formation (Tang, 2004; Yan and Tang, 2005). Thus, soil erosion, water erosion in particular, and associated yield suppression has been a serious problem threatening agriculture sustainability in the region for decades (Liu, 2004; Lu, 2001; Yang et al., 2003; Zhang et al., 2007; Wang et al., 2009). Soil erosion is a complex process that depends on soil type, ground slope, vegetation, and rainfall amount and intensity (Cui et al., 2007; Yan et al., 2008). Though soil erosion cannot be completely prevented, and it can be reduced to an acceptable level or soil loss tolerance (Morgan, 2005). Soil erosion prevention relies on selecting appropriate strategies for soil conservation. From the technical aspect, best approaches will adopt conservation tillage systems, install terraces, practice strip cultivation, apply fertilizers appropriately, use crop rotations and develop appropriate administrative policies.

This paper summarizes the agronomic, biologic and engineering practices for soil erosion control in this critical region and proposed strategies are discussed in the context of agricultural sustainability for Northeast China and similar regions.

2. Soil erosion control practices

Virtually all crop production in the Mollisols region is conducted using ridge cultivation up and down long slopes. This practice is historical and is the common practice on sloping farmland. Reductions or elimination of tillage is almost non-existent among local farmers. The existing practice leads to degradation of the granular particle structure, soil compaction, low water storage and reduced surface hydraulic conductivity (Niu et al., 2004). Additionally, increased use of small tractors since 1978, due to the household contract system, and a constant tillage depth have led to tillage induced hardpan formation, leading to the decline of water infiltration and storage in the region (Zhang et al., 2006a).

2.1. Basin tillage

As early as the 1940s, Chinese researchers understood the importance of basin tillage in reducing runoff and increasing crop yield. Using basin tillage for millet production on fields of 20 and 27° slope, runoff was reduced 83% and 47%, respectively, compared to the control in the ridge tillage up and down hill system; and millet yields were increased from 9% to 68% (Shen and Ren, 1995). However, the implementation of basin tillage in Northeast China was not adopted until the 1990s. Yang et al. (1994) stated that though the implementation of basin tillage needs extra input of 105 Chinese dollars (RMB) Yuan ha^{-1} compared to the common practice or ridge tillage, the net increased benefit is 660–680 RMB Yuan ha^{-1} in soybean and 1032–1080 RMB Yuan ha^{-1} in corn (Table 1). The economic output/input ratio of basin tillage is as high as 4–8 for soybean and corn fields in different locations (Table 2). This practice is applicable for all farmlands with slope greater than 6°. Soil type and crop type have varied responses to basin tillage. A general survey by our research group at different sites from rural communities in 2004 indicated soybean yield increased 39% and 23%, and corn yield increased 17% and 20% in Albic soil and Mollisols respectively (Table 3). A three-year demonstration of basin tillage in general state farms of Hei-long-jiang Province found yield was increased by 14.5%–22.8% in soybean and 16.2%–19.7% in corn (unpublished data).

The general practice involves building a small dike to form a basin within the furrow at certain distances along the row during the growing season. The determination of inter-dike distance is based on following equation:

$$L = 165.49\,\theta^{-0.47}$$

Table 1
Cost/benefit analysis of basin tillage (Yang et al., 1994).

Crop	Increased yield (t ha^{-1})	Increased benefit (RMB Yuan ha^{-1})	Labor (day ha^{-1})	Extra input (RMB Yuan ha^{-1})	Net benefit (RMB Yuan ha^{-1})
Soybean	0.33–0.34	660–680	10.5	105	555–575
Corn	1.72–1.80	1032–1080	10.5	105	927–975

Table 2
Net profit from basin tillage by labor construction.

Crop	Yield increase (kg ha^{-1})	Output increase (RMB Yuan ha^{-1})	Labor no. (ha^{-1})	Expenses fees (RMB Yuan ha^{-1})	Net increase (RMB Yuan ha^{-1})	Output/input
Soybean	341	612	15	120	492	4
Corn	1256	1130	15	120	1010	8
Soybean	471	849	15	120	728	6
Corn	1001	905	15	120	781	7
Corn	906	815	15	120	695	6
Soybean	509	661	15	120	542	5