Establishment of sown pastures in the hilly red soil region of the subtropics in southern China

OUYANG KEHUI1,2, WANG KUN1, LI DERONG2, LI ZHENMING3 AND LIU BING3
1 Institute of Grassland Science, China Agricultural University, Beijing
2 College of Animal Science and Technology, Jiangxi Agricultural University, Nanchang
3 Grassland Management Station of Jiangxi Province, Nanchang, China

Abstract

Grasslands are not only a fundamental natural resource for sustaining economic development, but also a vital strategic resource that can solve the conflict between short food supply and lack of arable land in contemporary southern China. In recent years, sown pastures have been established on many sites in the hilly red soil region of the subtropics in southern China with good results. Establishment of pastures is difficult because of the many environmental constraints. Based on past experience, recommendations for establishing pastures of introduced tropical and temperate species in Jiangxi Province have been made. Soil conservation is an important consideration when preparing a fine seedbed for grasses, and application of N, P, K and lime on infertile acid red soils is critical for successful establishment. For weed control, moderate grazing and herbicide application can play important roles. Other important issues to be considered are discussed.

Introduction

China is an agricultural country with 1.3 billion people. The conflict between short food supply and lack of arable land has become a bottleneck in the further development of the Chinese economy. The effective utilisation of wilderness is considered a very important strategic measure in supplying the food required for 1.6 billion people in the 21st century in China (Xin 2000).

The red soil region covers a belt c.1500 km long and 800 km wide, including most of the provinces of Zhejiang, Fujian, Jiangxi and Hunan, and parts of Anhui and Guangxi. The area includes more than 70% hilly and mountainous land, almost half of which has become an eroded wasteland as a result of excessive deforestation (Hacker et al. 2001). There is increasing pressure to develop these soils, due to population pressure and increased economic growth. In addition, there is increasing demand for livestock products, associated with economic change in the region. With some policies like ‘The National Poverty Alleviation Program’, ‘The Land Fertilization Plan’ and ‘The National Ecological and Environment Rehabilitation Program’ being implemented, ‘Forage Cultivation and Cattle Breeding’ has become a regional policy (Ren and Zhang 2002) and the red soil areas are used for fodder collection currently. Cultivation of forage not only promotes animal production but also reduces water and soil loss and may increase soil fertility (Li et al. 1996a; Zhang and Li 2002a; Liu et al. 2003a; Xu et al. 2004).

However, many difficulties exist in establishing artificial grassland, including unfavourable climatic conditions and infertile acid soils in the hilly red soil region of the mid-subtropics. Jiangxi Agricultural University and Grassland Management Station of Jiangxi Province have conducted many studies on establishing artificial grassland since the period of ‘The Sixth Five-Year Plan’ at the end of the 1970s in this region to generate a significant amount of information on forage species introduction, sowing, soil preparation, fertiliser application and weed control. Based on past experience, some recommendations on establishing artificial grassland in these regions have been made, based on conditions in Jiangxi (JX, a Province of southern China).
Farming systems

The natural grasslands in the waste hillside fields in southern China include secondary shrub-herbosas and secondary herbosas. These grasslands are low in quality and produce inconsistent yields. Cattle are raised with a combination of scattered grazing and feeding in small-sized pens (Zhou 1995). There is a need to increase the productivity and economic returns from grasslands and to ensure sustainable development of mountainous eco-agriculture (Yang and Zhang 1993; Zhou 1995; Xin 2002). Research has showed that establishing sown pasture could significantly improve pasture yield, vegetation cover and the proportion of edible forage (Yang and Zhang 2003; Yuan et al. 2005). Sown pastures were introduced to southern China many years ago and development has been rapid in the last decade. At present, the area of sown pasture in southern China is up to 1.3 M ha (Ouyang and Wang 2006), and these pastures play a major role in the sustainable economic development of hilly regions.

Local government allocations and some agricultural development funds from central government were the main source of finance for pasture establishment and management in the past. In recent times, private companies have participated to a much greater extent and invested in pasture development. A combination of sources for input of resources has been encouraged. Some management models like ‘examination station + demonstration pasture + households’, ‘enterprise + forage base + farmers’ and ‘intermediary agency + households’ were set up and developed. A number of large-scale intensive modernised units for raising beef cattle have been formed (Hong and Wang 2006). Farmers take greater interest in sown pasture because of the potential economic benefits. These family ranches can be less than 1 ha, where a cut-and-carry system is used to feed small animals like fish, geese and rabbits, small numbers of goats and draught cattle, or more than 10 ha, where some specialised stall feeding of beef cattle was tried (Li et al. 1998; Xie et al. 2003; Li and Wang 2004).

Natural situations

Jiangxi Province (24°29′14″–30°04′40″N, 113°34′36″–118°28′58″E), to the south of the Yangtzi River, has a total land area of \(167 \times 10^3 \text{ km}^2\), including \(60 \times 10^3 \text{ km}^2\) of mountainous and \(70 \times 10^3 \text{ km}^2\) of hilly land, with a population of 41.39 M people (2000 census).

Jiangxi Province has a subtropical monsoon climate, with mean annual temperature of 16.2–19.7°C, and an absolute minimum temperature of \(-12°C\) in January and absolute maximum of \(40+°C\) in July. Mean annual precipitation is approximately 1340–1940 mm (>98% falling as rain), with 55–60% occurring in March–June. Due to the abundant natural resources, potential forage production in JX is 10.8–15.2 t/ha DM per annum (Hu and Lu 1996), and the province is also one of the most important production areas for crops and commercial forests in China.

Environmental limitations

Cold snap in late spring

Rapid climatic changes, especially in late spring, can result in significant production losses (Fu et al. 1995). In late March–early April, cold snaps with a rapid drop in temperature can be produced by the cold north wind. Overcast and rainy conditions can be accompanied by snow with sub-zero temperatures. The cold weather may continue for up to 16 days resulting in frost damage to pastures.

Seasonal drought

The average rainfall distribution is 55–60% in March–June (wet season), 20% in July–September and 20–25% (dry season) in October–February (Xie and Xie 1996). In late March–April, with high temperatures and reduced rainfall, evaporation is at least twice rainfall. In Ji’an County, JX, evaporation from July–September can amount to 670 mm, which is 367 mm more than the precipitation (Xie and Xie 1996). In addition, the red soils have low water holding capacity, and seasonal fluctuation in available water levels in soil can affect production of shallow-rooted crops (Guo et al. 2003).

From 1950 to 1994, summer droughts occurred in JX in 10% of years, 17% of years having autumn droughts and 13% having droughts in both summer and autumn. A total of 19.4 M ha of land was affected by these droughts with an estimated reduction of 9.56 M tonnes in cereal grain production (Xie and Xie 1996).
Lean soil

Red soil is the zonal soil type in these regions. There are 93,000 km² of red soil in Jiangxi Province, accounting for about 56% of the total land area. Due to the high degree of weathering and leaching, electropositive ions of red soil have been depleted, and H⁺ levels in soil solution are high. The soil pH varies from 4.5 to 5.5. Almost all grasslands in southern China are lacking in N and organic matter, and an estimated 58% of grasslands are low in K, P, Cu and Zn (Xu et al. 1998). Due to a history of irrational development and over-utilisation, much of the vegetation on the slopes has been destroyed. In addition, denudation of the erodible soils has resulted in severe erosion, removing much of the topsoil. The combination of a thin layer of topsoil and low nutrient levels makes the introduction and production of sown species difficult (Guo et al. 2003).

Planting technology

Grass varietal selection

The natural, environmental conditions in the hilly red soil region are quite distinct from those in the mountainous region in the same latitude (Chen and Zhou 1991). Few grass species are adapted to the harsh conditions, and introduced tropical herbages often fail to survive winter temperatures, while temperate herbages find survival in summer difficult. The combination of acid and lean soil and seasonal drought makes it difficult to select grass varieties adapted to these conditions (Yi and Cheng 1994; Lin et al. 1998).

Hundreds of pasture species have been introduced and cultivated in past decades in Jiangxi Province. Species such as *Paspalum dilatatum*, *Paspalum wettsteinii*, *Paspalum notatum*, *Lespedeza cuneata*, *Chamaecrista rotundifolia* and *Lotononis bainesii*, with high yield and quality, great tillering ability, strong tolerance of low fertility and drought, and strong over-summering and over-wintering ability, were selected for use as permanent pasture (Zhan et al. 1991b; Yi and Cheng 1994; Ouyang et al. 1997, 2003; Shu 2004). Temperate herbages with strong heat-tolerance and high over-summering ability, such as *Festuca arundinacea*, *Dactylis glomerata* and *Trifolium repens*, could be planted on cultivated grassland to provide forage in winter and spring (Hu 1989; Cheng et al. 1991; Yi and Cheng 1994; Ouyang et al. 1997).

Pasture species which are well adapted to the region and produce high-yielding grasslands include: *Pennisetum purpureum* cv. Mott, *P. typhoideum*, *Euchasaena mexicana*, *Sorghum sudanense*, *Pennisetum clandestinum*, *Lolium multiflorum*, *Secale cereale*, *Bromus catharticus*, *Vicia sativa* and *Silphium perfoliatum* (Ying et al. 1998; Chen et al. 2002; Zhu and Zhou 2005).

Artificial grassland types

In Jiangxi Province, single-species grass pasture has been the common practice, mainly for ease of establishment and management. To increase the crude protein concentration and biomass of forage, more and more legumes have been introduced into pasture in recent years. This practice can increase not only animal production but also soil fertility significantly in the hilly region of southern China (Xu et al. 2001; Zhang and Li 2002b).

The optimal combination of species has been legumes such as *Lespedeza cuneata* and *Chamaecrista rotundifolia* with grasses like *Paspalum dilatatum* and *Paspalum wettsteinii*, or *Trifolium repens* and *Lotononis bainesii* mixed with *Festuca arundinacea* and *Dactylis glomerata*. The ratios of plant numbers of legumes to grasses have ranged from 1:4 to 1:1 (Mo et al. 2000; Yang and Zhang 2003; Luo et al. 2006). To avoid weed invasion and soil loss, pure legume stands are not sown in these regions because of low growth rates in the seedling period.

Ground treatment and soil preparation

Suitable soil preparation before establishment of grassland is very important to reduce weed competition and to increase seedling survival rate. The common methods for ground treatment are to grub out weeds and shrubs by hand or machine, while burning down after application of herbicide is an alternative. At this stage, the site is often levelled off by bulldozer, followed by ploughing, power-harrowing and rolling to create a firm, fine seedbed. The remnant roots of weeds and shrubs should be cleaned out after ploughing to prevent suckering. Soil should be cultivated to 20–25 cm depth, to destroy existing vegetation.
and to promote root development in the sown species to increase the drought-tolerance of the stand (Zhan et al. 1991a).

Land preparation should occur in July or December because of the reduced rainfall in these months. Before sowing, about 15–20 days after rain, land should be harrowed to preserve soil moisture (Zhan et al. 1991a).

The traditional overall ploughing method is inappropriate for use on slopes of more than 25°, with the band plough and cave plough being appropriate for these situations. Unlike on level ground, the preparation of a fine seedbed is not warranted, as heavy rain after sowing can cause erosion, washing soil and seed into the gullies. Moreover, the rain can cause surface-sealing making it difficult for seed to germinate. If ground is left in rough condition, rainfall penetrates the soil, runoff is reduced and seeds lodge in hollows (Liu et al. 2003a).

With the increasing awareness of soil erosion, zero-tillage technology and the use of herbicides were recognised in recent years to control weeds efficiently without any damage to soil structure on the slopes. The traditional tillage methods practised by farmers resulted in 33.2 m³/ha runoff and 167.8 t/km² soil loss per year, while using sequential herbicides reduced surface runoff by 20.8–47.7% and reduced the soil loss by 39.0–55.2% (Shui et al. 2003).

Ground preparation also affects the grass: legume ratio of the establishing grassland. In the early stage of establishment of pasture, loosened soil is of great benefit to grass growth. However, sowing on to undisturbed soil is unsuitable for growth of grass or legume (Liu et al. 2003a). The appropriate methods of ground preparation are manual prong or cave plough, which could increase seedling emergence rate by 36% and 34%, respectively, above no ground preparation (Liu et al. 2005).

Sowing time and methods

Research has shown that sowing date is the key factor for sward establishment without irrigation in upland areas (Li et al. 1999).

Temperate forage species can be sown in autumn or winter, and the best time is after the dry period in autumn (September–October), but not later than December (Zhan et al. 1991c). Pastures sown in autumn rather than winter have a longer growth period, which improves survival in the next summer. In addition, species can cover the ground earlier to decrease soil and water loss in the next rainy season. Sowing early can increase ryegrass yield, e.g. growth of ryegrass sown on October 18 exceeded that of ryegrass sown on November 27 by 3000 kg/ha at the first cutting (Pan 1996). However, forage sown early can experience lingering autumn drought during the seedling period.

For tropical forage species, the optimal sowing time in Jiangxi is in spring (end of March–end of April) but not later than May, which is later than in the neighbouring Hunan Province (Wen et al. 1998). Increasing sowing rates for grass could allow more rapid ground coverage and limit weed growth (Chen and Zhou 1991).

Broadcasting is the most economical sowing method, but seed can often be scoured by rain and may show damping-off symptoms in plots or growth in tufts, especially in rainy springs. The results of many experiments showed that sowing in rows produced more rapid establishment and a higher forage yield than broadcasting (Zhang et al. 1998). Drilling of seed and soil coverage result in better establishment than broadcasting with no soil coverage (Zhan et al. 1991c). Optimal sowing depth is generally 0.5–1.5 cm. In the sticky clay of red soil, when the depth exceeds 2.5 cm, seed will sprout erratically (Zhan et al. 1991c).

Seedling-period management

In general, the pasture should have established within 60 days after sowing in JX (Chen and Zhou 1991). However, the severe climate after sowing, especially dry conditions, can suppress germination and cause death of seedlings. At the same time, weeds, which are adapted to the conditions, can spread and compete with the establishing pasture seedlings (Li et al. 1991).

It is important to maintain soil moisture levels during this period. Limited irrigation will promote earlier and more uniform germination after sowing. Applying carbamide at 30 kg/ha at this time will control weeds and allow seedlings to grow with reduced competition (Liu et al. 2003a).

Fertilisation

Since deeper soils on smooth terrain in populated southern China are all used for farming,
sown pastures are always established on infertile, shallow soils, so fertiliser application is a very important measure to gain high yield and high quality forage in these regions.

In the infertile red soil region, serious P deficiency is the important nutrient deficiency for pastures (Xu et al. 1998; Jiang et al. 2002). The total P content in red upland soil is very low (around 1.0 g/kg), and P-fixation by these acid red soils results in low P availability (Zeng et al. 2006). It is estimated that the P-fixation capacity in southern China (111 samples) ranges from 58 to 1297 mg/kg P, which is equivalent to a fixation of 130–2900 kg/ha P (Zhao 2002). Usually, the available P content in red soil is 10 mg/kg, and may be lower than 5 mg/kg in some areas, so the effects of P fertiliser on forage establishment and yield can be significant (Xu et al. 1998). Research in JX (Li et al. 1996b; Liu et al. 2003b) has shown that all pastures (grasses, legumes and mixed pastures) benefit from application of P fertiliser. In the newly established artificial grassland in Qingjiang County, JX, the order of the effects on forage yield was P>N>K (Chen and Zhou 1991). P fertiliser should be applied early in the establishment phase, because of the slow release rate. While phosphate fertiliser is usually mixed with seed and scattered in the seed ditches at sowing, it can also be applied as a basal dressing. Application rates of 24.5 kg/ha P are recommended (Liu et al. 2003a).

Applying lime to acid red soils can increase soil pH and reduce P-fixation, with improvement in pasture growth, especially of legumes (Xu et al. 1998; Liu et al. 2003a; Li et al. 2006). The lime can be applied during soil preparation, preferably 6 months before sowing, and thoroughly mixed with soil during ploughing. The optimum rate of limestone is 750–1125 kg/ha (Liu et al. 2003a). Pastures should be re-fertilised with P and lime every 3–4 years.

Some research suggests that toxic levels of exchangeable aluminium in the soil should be eliminated when soil pH reaches 5.6–5.7 and the content of solute and exchangeable aluminium in the soil declines to less than 10 percent of effective cation exchange capacity (Ding et al. 2003). The recommendation is to use alkaliescent fused calcium magnesium phosphate instead of alkali limestone (Xu et al. 1998). However, applying limestone is the most convenient and efficient method to increase the pH of the acid red soil, especially when the pH is less than 5.0.

In the infertile red soil region, researchers in JX (Cao 1994; Pan 1996; Liu et al. 2003a; Yu et al. 2004; Li et al. 2005) have demonstrated the importance of N for forage dry matter accumulation, especially for grasses. In some cases, N-fertiliser results in larger responses than P-fertiliser (Cao 1994; Yu et al. 2004). To promote tiller growth in the early stages and increase seedling survival rate, the optimal application of N is 25–30 kg/ha N for tropical forage species and 22.5 kg/ha N for temperate forage species (Liu et al. 2003a).

While K in red soil is normally adequate, it exists mainly in a form unavailable to plants, which results in reduced grass growth. It is very important to provide adequate K for high-yielding pasture. While appropriate K-fertiliser levels depend on the effective K content of soil (Jin et al. 1994; Yu et al. 2004), an application rate of 42 kg/ha K at the tillering to jointing stage is recommended for best results (Liu et al. 2003a).

While individual application of N, P or K can increase grass yield, application of a mixed fertiliser provides best results (Li et al. 2004). For example, the yield of perennial ryegrass increased by 180% with 90 kg/ha N, and 30% with 54 kg/ha P but 330% with a compound N-P-fertiliser, the interaction between N and P being highly significant (Cao 1996).

In general, Astragalus sinicus, Sesbania cannabina, Vicia sativa, Lolium multiflorum and Raphanus sativus can be used effectively as a green manure to increase soil nutrient levels before the establishment of permanent grassland (Cao and Chen 1993; Li and Cao 1995; Mao et al. 1997; Yang et al. 1998).

**Weed control**

Invasion by environmental weeds is a serious threat to pastures in southern China and weed invasion represents the primary cause of grassland degeneration. In hilly regions of JX, there are numerous species of wild weeds, including 733 species from 347 families (Ji et al. 2003). The main native species in this region include: Imperata cylindrica, Miscanthus sinensis, Artemisia argyi, Erigeron canadensis and shrubs such as Rosa laevigate and Clerodendrum cyrtophyllum. Native weeds have advantages in high resistance to environmental stress, fast growth, high yield and longer life cycle, and are very
aggressive (Shui et al. 2003). Numerous studies have showed that pasture swards on red soils were seriously infested by weeds, especially in summer (Li et al. 1999).

The common methods for controlling weeds and shrubs are manual control, mechanical control, biological control (moderate grazing) and chemical control (Li et al. 1991; Huang et al. 2003).

The manual method is suitable for controlling weeds in small areas and scattered pieces. If the weeds spread to a larger area, ploughing followed by clearing out of residual weed roots is recommended (Li et al. 1991).

In the tillering or branching stage, moderate grazing can promote grass tillering or branching to cover the surface rapidly, thus increasing competition for weeds. Biological control is well suited to esculent weeds such as Imperata cylindrica. Heavy grazing and trampling could be conducted to suppress the regrowth of weeds, with rotational grazing better than uncontrolled grazing. In an experiment in Qingjiang County, JX, rotational grazing reduced the weed diversity or DM yield by 50–65% (Chen and Zhou 1991).

Application of chemical herbicides could be an even more efficient method (Lan and Yao 1991). It is time- and labour-saving, highly efficient and inexpensive and can have long-term residual effects. Chemical control can be an integral part of modern grassland management. Spraying with glyphosate can kill 95% of shoots and rhizomes of Imperata cylindrica. It costs much less than manual cultivation and produces significant results (Zhang and Wen 1998).

Conclusion

For sown pasture development to increase rapidly in the area, adequate supplies of pasture seed are needed. Therefore, establishing seed production bases to provide adequate supplies of good quality seed is essential for effective development of grassland husbandry. Subdivisional fencing should provide for a rotational grazing system on the sown pasture. Bio-fences may be the best choice, given the abundant supply of edible leguminous trees and shrubs in southern China, which could supplement the limited supply of legumes in the pasture. An improvement in the level of mechanisation is important to increase productive efficiency and to permit the development of larger areas of sown pasture. With the complex landforms, the scattered distribution of grasslands and operators with limited formal education, medium-small and semi-automatic machinery, combined with animal power, would seem appropriate. This has the characteristics of simplicity, ease of operation and stability and has performed well in profile modelling. In any case, the new technology of establishing sown pasture needs to be made popular and applied in practice, especially in hilly regions of southern China, where farmers are accomplished in planting rice, but lack skills to plant forage. Constructing an efficient institute for educating the key groups about sown pasture technology and disseminating the technology is an important step in achieving the potential for sown pastures in the Province.

References


Xie, MINGQING, WEN, SHILIN and CAO, JUSHENG (2001) Effects of different forage planting model on soil and water
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