Ecological Engineering 102 (2017) 55–63

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

# Effects of different types of mulches and legumes for the restoration of urban abandoned land in semi-arid northern China

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ARTICLE INFO

*Article history:*
Received 30 August 2016
Received in revised form 29 January 2017
Accepted 2 February 2017
Available online 17 February 2017

*Keywords:*
Abandoned land
Ecological mulches
Soil physicochemical properties
Vegetation recovery
Evaporation

ABSTRACT

Abandoned land is a type of resource wasteland that significantly damages the ecological environment and affects city construction. The northwestern Chinese ecological environment of the semi-arid field is fragile and susceptible to temperature variability. It is difficult to transform such abandoned land into sustainable urban land. However, vegetation restoration on urban abandoned land can ameliorate the soil conditions but received less attention. In the ecological restoration of such abandoned land, the use of certain types of mulch and legume is efficient and effective. In this research, three mulching methods, including a straw blanket (SB), bark plot (BP) and wood shavings (WS), and a control plot (CP) were evaluated over separate growing seasons to determine their effects on the vegetation biomass and the soil physicochemical properties, including soil temperature and soil moisture. The results indicated that mulching had multiple benefits, including improved vegetation growth by decreasing soil evaporation and regulating the soil temperature. SB and BP were the preferred materials because they were more effective. The wood shavings method did not favor the establishment of vegetation and resulted in vegetation similar to that of the control plot. In addition, the legumes *Amorpha fruticosa*, *Lespedeza bicolor* and *Medicago sativa* significantly enhanced the soil physicochemical properties. Thus, the straw blanket, bark plot mulch are recommended for a beneficial water retention effect on topsoil and vegetation growth of abandoned land. This ecological restoration technology for urban abandoned land also exhibits environmental friendliness and sustainability.



## 1. Introduction

With urbanization and the changing industrial structure, increasingly more land in urban areas has been abandoned. This abandoned land not only results in a waste of resources and energy as well as ecological destruction but also restricts the orderly development of the urban landscape. Urban wasteland is the inevitable product of the city in its development. No city can avoid the question of how to restore such land. According to the philosophy of sustainability, urban abandoned land should be restored using ecological methods. The researchers could convert such abandoned land from a passive state to an active state and thus change "waste" to "treasure", producing new vitality for the urban environment (Cano et al., 2002; Linda, 2007; Liu et al., 2013).

In northwestern China, a conflict between urbanization and the fragile ecological environment has gradually developed. However, in semi-arid environments, the establishment of vegetative cover on abandoned land is particularly challenging because it is often limited by high evaporation and temperature variability (Liu et al., 2013). High evaporation by strong winds also results in low soil moisture and unfavorable conditions for plant germination and growth. Vegetation recovery could have a positive effect on abandoned land. Plants may improve the surrounding microclimate by transpiration, such as through variation in layering, which can produce different temperature and humidity levels. Thus, the plant community plays a key role in the ecological environment (Cao et al., 2010; Fehmi and Kong, 2012).

Mulching measures and vegetation play an important role in the restoration of urban abandoned land. The soil surface of such land is prone to exhibit low infiltration and high evaporation, which may cause high plant mortality and makes the establishment of vegetation difficult (Cano et al., 2002; Hazlett et al., 2007). Additionally, temperature stress could influence the initial stage of vegetation restoration on abandoned land (Beikircher et al., 2010).

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http://dx.doi.org/10.1016/j.ecoleng.2017.02.001
0925-8574/

In restoration work, plant species should be selected that have a high seed-germination rate and excellent resistance to drought stress, alkali stress, heavy-metal stress and aridity stress. The plants should develop deep root systems, grow rapidly and improve the soil's organic, physical and chemical properties. It is better to select favorable indigenous species and native pioneer plants, considering the economic benefits. In particular, leguminous plants could survive well in low-nutrient soil and under climatic stresses (Spehn et al., 2002; Yang et al., 2016). During the initial stage of land reclamation and ecological restoration, the choice of plant species is critically important. In designing the vegetation community composition and structure, configuration restoration ecology and landscape ecology can be adopted. In this way, the ecological restoration can create a suitable diverse space for plant life and avoid interspecific competition while promoting stability. To increase species diversity and strengthen community structure, urban abandoned land should be designed as mixed afforestation or as a diverse community. The vegetation should mimic the vegetation structure of natural ecosystems by mixing the tree, shrub and grass hierarchy (Jenerette et al., 2007; Victor et al., 1999).

Mulches provide aesthetic, economic and environmental benefits to urban abandoned landscapes. Mulching is particularly useful in the establishment of trees in landscapes that receive minimal care, such as restoration sites (Fehmi and Kong, 2012). Generally, mulches can improve soil health by reducing soil moisture evaporation and creating healthy populations of plants and associated animals (Ji and Unger, 2001; Smith and Johnson, 2004). Many studies have established that mulch use has many benefits, such as reducing soil erosion and compaction, maintenance of the optimal soil temperature, aesthetic improvement and economic value. Biodiverse, stable landscapes are more resistant to stress, are more aesthetically pleasing, require fewer applications of pesticides and fertilizers, and are more sustainable than those without mulch cover (Ledgard and Steele, 1992; Linda, 2007; Yang et al., 2016). When the soil is insufficient, coverage materials, such as mulch, can improve the vegetation growing conditions. For example, the interacting factors in a green landscape were identified in the United Kingdom, where the plant cover of several early communities increased up to 15 times that of controls with increased nutrient availability and protection against seed input but only seven times when only one of these two factors was present (Balvinder et al., 1988).

Bioremediation refers to the use of plants, animals, soil and soil microbial life activity and its metabolites to alter the chemical properties and physical structure of the soil while enhancing soil fertility. Bioremediation could degrade, absorb or purify soil contaminated by pollution. The physical and chemical modification of the soil is expensive. However, because bioremediation can simultaneously change the environmental quality of air, water and soil, it could reduce pollution that is hazardous to humans and promote landscape development (Tanaka and Hashimoto, 2006; Yang et al., 2016).

Many studies have established that legumes could be used in renovating abandoned land to extract, decompose and transform fixed soil sediment, sludge or groundwater hazardous substances. The literature demonstrates that grass–legume mixture can grow in the soil of abandoned land and provide nitrogen-rich mulch for soil, have a significant beneficial effect on soil fertility and act as pioneer plants to improve nutrient-poor soil (Agbenin and Adeniyi, 2005). In particularly, the legumes improve the soil's nitrogen accumulation. The following legume pioneer plant species have a nitrogen fixation capacity: *Albizia julibrissin, Amorpha fruticosa, Trifolium repens, Lespedeza bicolor* and *Medicago sativa*. The literature indicates that the soil's physical and chemical properties can improve steadily by phytoremediation after several harvests (Long et al., 2001; Sawtschuk et al., 2012).

**Table 1**
Equipment performance of Watchdog.

| Measurement content | Measurement scope | Precision |
|---|---|---|
| Wind speed | 0–241 km/h | ±6% |
| Relative humidity | 10–00% (when 5–50 °C) | ±4% |
| Air Temperature | −32 to 100 °C | ±0.5 °C |
| Solar radiation | 0–1500 walts/m$^2$ | ±7% |

The category and quality of mulch and other soil covers, the potential for soil evaporation and gulley formation, the amount of time abandoned age of construction and the surrounding vegetation is factors that affect early ecosystem development. In addition, the effects of legume treatments must be evaluated within variable green land structural features (Maiti, 2013; Maiti and Maiti, 2015). The objective of our research was to determine whether mulches and legumes would contribute to improving successful soil preparation, soil amendments and evaporation control in green land reclamation of abandoned land, which verified the effect of improving soil physicochemical properties due to the growth of vegetation.

## 2. Materials and methods

### *2.1. Study sites*

The research was performed at Xi'an University of Architecture and Technology in Xi'an City, Shaanxi province, China. The site was located in the abandoned land not only results in a waste of resources and energy as well as ecological destruction but also restricts the orderly development of the urban landscape. It was located in the semi-humid area of northwestern China at 345 m elevation. The annual average tace and at a 1.5 m height using a small Watchdog (USA, 2900 ET) meteorological station (Fig. 1; Table 1).

### *2.2. Soil treatments*

In this study, three types of mulch were used. The first, a straw blanket (SB), was made from wheat straw. The SB thickness was 10 mm, and the weight was 350–400 g/m$^2$. In addition, a bark plot (BP) was applied. It had one layer, which was made from durable polypropylene. Thus, the BP was thinner (2 mm) and lighter (80–100 g/m$^2$) that the SB. Wood shavings (WS) were also used. The wood shavings were fine screened from pine and white spruce wood. Manure was applied at 30 Mg/ha and wood shavings at 11.25 Mg/ha and then incorporated into the soil at 5–10 cm with rakes and shovels. A control plot (CP) was also established (Fig. 2).

### *2.3. Plant species*

Five types of legume were used in this study. The plant seeds primarily consisted of *Amorpha fruticosa*, *Lespedeza bicolor*, *Medicago sativa*, and *Pop annua* (ratio: 1:1:1:1; w/w). These plants are native species and possess the following characteristics: fast growth, drought resistance, tolerance for lean soil, developed root systems and exuberant branch and leaf growth. The seeding density was approximately 30 g/m$^2$ of uniformly mixed seeds.

### *2.4. Measurements*

In 2015, four experimental field plots were established according to the following treatments: SB, BP, WS and CP. The area of each plot was approximately 140 m$^2$ (10 m long and 14 m wide). Soil-condition and plant-growth monitoring were performed in the following years. For each field plot, four observation points were established in an urban green area for comparison. These observa-