

Revisiting Sustainable Development of Dry Valleys in Hengduan Mountains Region

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Abstract: Dry valleys are a striking geographic landscape in Hengduan Mountains Region and are characterized by low rainfall, desert type of vegetation and fragile environment. Past efforts and resources have been concentrated mainly on rehabilitation of degraded ecosystem and fragile environment, particularly reforestation, while socio-economic development has been largely overlooked. Despite successes in pocket areas, the overall trend of unsustainability and environmental deterioration are continuing. It is important to understand that uplift of the Tibetan Plateau is the root cause of development of dry valleys, and development and formation of dry valleys is a natural process. Human intervention has played a secondary role in development of dry valleys and degradation of dry valleys though human intervention in many cases has speeded up environmental degradation of the dry valleys. It is important to understand that dry valleys are climatic enclaves and an integrated approach that combines rehabilitation of degraded ecosystems and socio-economic development should be adopted if the overall goal of sustainable development of dry valleys is to be achieved. Promotion of niche-based cash crops, rural energy including hydropower, solar energy, biogas and fuelwood plantation is recommended as the priority activities.

Keywords: Natural process; climatic enclave; root cause; human intervention; secondary role; harmonious development; niche-based crops; rural energy.

Introduction

Sustainable mountain development has attracted both international and national attention after great efforts made in the past two decades. Unfortunately, mountain ecosystem and mountain natural resources are still characterized by unsustainable trends, though there have been improvements in some specific fields and in some geographical regions. While research on rehabilitation of degraded mountain ecosystems, such as revegetation / reforestation, has attracted huge governmental and international investment, sustainable rural economic development in many dry valleys in Hengduan Mountains Region has been largely overlooked, except for increasing investment in tourism development in the region.

Hengduan Mountains Region is well known for its unique topography, extremely rich biodiversity, rich cultural diversity, highly diverse environment, and unique landscape. Apart from these, Hengduan Mountains Region is also characterized by highly developed and highly concentrated dry valleys along rivers. Occurrence of dry valleys is a very striking geographical

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landscape in the Hengduan Mountains Region, and the dry valleys are widely found in the main rivers and their tributaries in this region, notably along the upper Yangtze (Jinsha), Dadu, Yalong, Min, Lancang (Mekong), Nu (Salween), and Yuan (Red) and their tributaries. Compared to the neighboring areas, the dry valleys are characterized climatically by much less rainfall and higher temperature and evaporation. Environmentally dry valleys are among the most fragile and degraded ecosystems in Southwest China. Socio-economically, most dry valleys are among highly populated areas and are often centers of human settlements and of agricultural development. Many dry valleys also belong to poverty areas. Due to ever increasing population pressure, inappropriate management of natural resources, and probable impact of global changes, most of dry valleys have been caught on a vicious cycle of over-exploitation of natural resources, degraded environment and poverty.

Immense efforts and investments have been made in the past, especially in the past two decades in economic development and rehabilitation of degraded mountain ecosystems. Many dry valleys have been developed into main production bases of off-season vegetables, fruits, medicinal plants, and some other cash crops. With rapid globalization development, however, these sectors in dry valleys will be faced with great challenges. Comparative advantages in the past might become constraints today and in the future. Problems of marketing local products have already become a big problem in some dry valleys. Similarly, constraints in the past might become comparative advantages today and in the future, which, however, needs careful and appropriate analysis of local biophysical conditions and other factors. One main objective of this paper is try to analyze the past efforts and shed some lights on how to harness the unique natural and social resources for sustainable development of the dry valleys in the Hengduan Mountains Region .

1 Characteristics and Change Trends of the Dry Valleys

Dry valleys refer to the river valleys along the main rivers that have much drier and hotter climate compared to their neighboring areas, usually separated by mountains. Notably, dry valleys are found in the main rivers of the Jinsha, Nu, and Lancang and their tributaries. The well-known dry valleys in the Hengduan Mountains Region include Yuanjiang, Nujiangba, Yuanmou, Panzhihua, Maoxian, Nanjian, etc. Though also found in some other countries, the dry valleys in Hengduan Mountains Region are the most remarkable in terms of their geographical coverage and concentrated occurrence. Many of the dry valleys have been centers of economic and agricultural development and human settlements. These dry valleys will also have important impact on sustainable development and management of natural resources and environment in the whole river basins.

Dry valleys are characterized by a combination of a number of features. Geomorphologically, dry valleys are usually characterized by combination of high mountains and deeply dissected rivers. Valleys are usually narrow. Climatically, dry valleys are characterized by low rainfall, high temperature, high solar radiation, and high potential evaporation. Climate of dry valleys and non-dry valleys on two sides of a mountain is considerably different. Maoxian and Nanbaoshan of Qionglai, for example, are separated by Longmeng Mountain and Chaping Mountain and are located in the west and east sides of the mountains, respectively. Annual rainfall in Maoxian is less than 500mm compared to 1569 mm in Nanbaoshan. Though Nanbaoshan is located south to Maoxian, its monthly temperature in January and July and its mean annual temperature are 1.0 °C lower than those in Maoxian, respectively (Table 1).

Table 1 Comparison of temperature and rainfall in a dry valley and a non-dry valley

Location	Altitude (m)	Mean temperature (°C)			Rainfall (mm)		
		January	July	Annual	January	July	Annual
Maoxian	1580	0.6	20.5	11.0	2.9	92.7	494.8
Nanbaoshan	1552	-0.4	19.5	10.0	25.7	322.9	1569.2

Source: Shi Chengcang & Luo Xiuling, 1999.

This is because Maoxian is a typical dry valley and Nanbaoshan is located in humid climate region. Most of the dry valleys are located within the regional centers of the lowest rainfall and highest temperature. The lowest rainfall in Southwest China is found only in dry valleys (Bengzilan 336 mm, Derong 325 mm) (Wen Chuanjia, 1989). Vegetation is poorly developed and usually is of desert vegetation type consisting of typically xeromorphic species of herbaceous plants and dwarf shrubs. Vegetation coverage is usually low. Environment in dry valleys is very fragile and highly prone to desertification. Soil erosion, both wind and water erosion, is severe. Natural hazards are frequent.

Based mainly on different temperature regimes, it is widely accepted in China that dry valleys in the Hengduan Mountains Region are divided into three types, namely, dry-hot, dry-warm and dry-temperate valley (Zhang Rongzhu & Liu Yanhua 1992, Zheng Du & Yang Qinye 1992) though dry valleys are sometimes divided into four types, i.e., dry-hot, dry-warm, dry-temperate and dry-cold valley (Li Mingsen 1991). Within each type, subtypes are further divided according to moisture /aridity regimes (Zhang Rongzhu & Liu Yanhua 1992, Zheng Du & Yang Qinye 1992). Each type of dry valleys has its own combination of different biophysical conditions, and its economic development activities and strategies for sustainable development are also different considerably. Occurrence of different types of dry valleys has exhibited latitudinal zonal feature. In general, the dry-hot valleys are located in the southern part of the Hengduan Mountains Region and the dry-temperate type occurs in the northern part of this region, while the dry-warm type occurs in between the above two types.

Some visible trends have been observed in dry valleys. Among these include expansion of dry area in both altitudinal and geographic range, ascending of lowest vegetation line to higher altitude, deteriorating environment, increasing soil erosion, more frequent landslides, and increasing negative impact of degraded environment on lowland. All of these changes will have direct or indirect impact on economic development orientation and strategy for environmental conservation in dry valleys.

2 Causes of Dry Valley Formation and Environmental Degradation

There are a number of hypotheses about the formation of dry valleys. Though foehn has been regarded as a key contributing factor to the formation of dry valleys, Zheng Du and Yang Qinye (1992) provided a comprehensive analysis about causes of dry valley formation. According to them, formation of dry valleys is complicated, including impact of the Tibetan Plateau on vertical air circulation, effect of different geomorphology, air circulation within dry valleys, and human interventions. We think that the alternative occurrence of south-north high mountains and deeply dissected rivers in this region may play an important role in development of dry valleys and in facilitating formation of foehn. Quick uplift of the Tibetan Plateau might have maximized the effect of geomorphology and effect of foehn on formation of dry valleys. Therefore, the uplift of the Tibetan Plateau might be the root cause of the dry valleys, because the uplift of the Tibetan Plateau has caused most of the changes discussed by Zheng Du and Yang Qinye (1992) and strengthened the effects of foehn.

Environment is very fragile in almost all the dry valleys of the Hengduan Mountains Region. Environmental degradation and deterioration in dry valleys is widely accepted and well known. However, it does not mean that environment in the whole valley of any specific valleys is fragile, different from regions to regions. The fragile environment is found usually in the really dry zone of a dry valley, which usually covers a vertical range of several hundred meters from river bottom. Most of the environmental problems often originate from this zone and vegetation is poorest in this zone. Above this zone, mainly due to better moisture regime, vegetation is usually much better if other factors allow development of good vegetation. Usually, development activities have been confined to the bottom of dry valleys. Land in the bottom of dry valleys is intensively used. Therefore, problems are on a zone above the bottom and below natural vegetation line. This is also the area where future work is needed.

Valley bottom of many dry valleys in the region is the real production center. Cropland

accounts for a very low rate of land. For example, in the upper Min River, cropland accounts for only 1.46 % (Lu Xiaoyang 1999), very much lower than 10 % of the average for Sichuan. Though the land area is small, most human activities are concentrated on this area and it is the land resource most important for local people (Zhang Yiguang 1989). Due to availability of very small productive land and increasing population pressures, human activities, mainly agricultural activities, have been expanded to very fragile slopes of valleys, which has been another important factor for deteriorating environment in the dry valleys.

Soils in most dry valleys are very erosive and soil erosion in dry valleys is often among the most severe in a region. Most severe soil erosion, for instance, is found in dry valleys of Lancang River at Nanjian and Deqin (Wang Hong 1997) and in the dry valley of the upper Min River from Mianchi to Zhenjianguan (Guo Yongming & Tang Zongxiang 1995). In addition, mountain hazards occur more frequently in dry valley than in other adjacent areas.

In conjunction with deteriorating environment, expansion of dry valleys has also been observed in various dry valleys. Dry valleys are expanding on two dimensions. They are expanding at the two ends of the river as well as expanding to higher altitude. Some other obvious changes have been observed, including reduced rainfall, increased temperature, and increased wind speed and windy days. The causes of environmental degradation in and expansion of dry valleys, however, are thought different by different people. Deforestation (Shi Chengcang & Luo Xiuling 1999) or deteriorating climate (Ye Yanqiong *et al.* 2002) has been regarded as the key contributing factor. While human intervention indeed plays an important role in development of dry valleys and environmental

changes, it is very important to understand that development of dry valleys is a natural process. Human activities can play only a secondary role, either speeding up or slowing down the process. Atmospheric circulation, geomorphology and global change might be the root causes of environmental changes in dry valleys.

3 Experiences and Lessons Learnt from Past Work in Dry Valleys

Despite the above mentioned constraints and environmental problems, efforts must be made to meet increasing demand of local population without further damage to local environment because local people have rights to live better. In addition, upland and lowland interaction has also required better and more environment friendly management and sustainable development of dry valleys.

Dry valleys have been exploited mainly as resources in terms of temperature and solar radiation, and many dry valleys have been developed in the past two decades into important production bases of cash crops, such as off-season vegetables. Some of these production bases are listed in Table 2. More work, however, is needed in planning specific niche-based crop development in different dry valleys.

Apart from agriculture-based activities, most of the past work on environmental conservation of the dry valleys has been focused mainly on rehabilitation of degraded ecosystems. Rehabilitation of degraded ecosystem in many dry valleys means revegetation only, especially reforestation, because revegetation has been managed by forestry sector.

Table 2 Some cash crop production bases in dry valleys

Sectors	Main localities
Off-season vegetables	Yuanmou, Miyi, Hanyuan
Apples	Maoxian, Lixian, Jinchuan
Huajiao	Hanyuan, Maoxian, Lixian
Tropical fruits (e.g., mango, litchii, banana)	Yuanjiang, Panzhihua, Nujiangba
Specific economic cash crops (e.g., agave)	Baoshan, Yuanmou, Yongshan

Though most of huge investment has been spent on tree planting, real success has been very few. In the dry valleys of the upper Min River, for example, revegetation has been concentrated on tree planting even though it was realized that this area might not be suitable for tree planting and tree growth. In 1950s, transplanting of saplings was used but all failed except for a very few spots with better soil moisture. The key cause of failure was considered to be unsynchronous temperature increase and availability of rainfall during spring because quick increasing temperature in dry valleys in spring led to early growth of roots but rainfall is not available until two months later. This unsynchronicity of temperature and rainfall and lack of soil moisture led to dying of tree saplings. In 1960s, in order to ensure survival and growth of planted saplings, land was prepared along contour lines. Most importantly, water was uplifted from the Min River to irrigate saplings 3 - 5 times a year. As a result, more than 80% of planted saplings survived. However, these survived trees have to be irrigated at least two times a year to ensure their survival, which proved to be not realistic for revegetation in the region (Liu Xinghua 1985). In addition, a large scale and continuous irrigation will also lead to more soil erosion, land slide and debris flow because of local geological and geomorphological conditions. Irrigation induced landslide resulted in destruction of an apple orchard was reported already in Wenchuan of the Upper Min River (Wang Jinxi 2001).

A major constraint with such approaches is that these trees have to be irrigated every year by uplifted water from river, which has made such an approach very unreasonable and cannot be replicated in other places, because this method is very expensive. It costs over 30,000 yuan/ha in such afforestation efforts (Chen Guojie 2001). More problematically, trees will die when irrigation stops. The quantity of water need to ensure survival and growth of trees will increase with time because growing trees need more water. Further, water will become another limiting factor for economic development in the future. Use of water for such purposes and / or in such a big amount will soon becomes not economically viable.

Since past work has focused on reforestation,

problems that local communities have been faced with are largely overlooked by both most research and government institutions. Apple and huajiao, for example, are the major income sources for the local community in dry valleys of the upper Min River. Local people has been benefited high income before 1998, but due to arrivals of many other better varieties of apples from other parts of China and even from other countries, market demand for the apples produced there have declined drastically (Bao Weikai *et al.* 2003). Similarly, huajiao has been a very important source of income in the same area, but due to some unknown reasons, most of the huajiao trees died, which has also caused decreased income. Both cases suggest that either social or natural reasons could lead to change in income patterns. Unfortunately, though these two problems have been well recognized in the region, no research institutions have tried to involve in solving them. Research institutions have been interested in and concentrated on so-called "important" research activities but have actually been working on problems that might be easily addressed or in the areas that are not difficult to work with. For local people the benefit they get from the research institutions and programs are basically labor wages.

Apart from the above mentioned lessons, there are also some knowledge gaps. Though dry valleys are widely distributed in the Hengduan Mountains Region, most research resources are used in only a very few dry valleys, such as the Upper Min River, Yuanmou and Nanjian of the Jinsha River basin. There are many dry valleys in which little rehabilitation and economic development work has been carried out. These neglected dry valleys are also important if an overall goal of reconstruction of degraded environment in West China is to be achieved. Further, deforestation has been regarded as the key cause of dry valley formation and development, but impact of the Tibetan Plateau uplift is largely overlooked and impact of global change is almost completely overlooked.

4 Strategy for Sustainable Development in Dry Valleys

It is very important to understand that dry

valley is an objective presence and a natural landscape. What we can do is how to promote harmonious development rather try to fight against the nature. Experiences of reforestation in such dry valleys as the upper Min River have sufficiently indicated a need to revisit our development and revegetation strategies / programs. Setting of appropriate development strategies can be made only after a full and right understanding of the studied subject. It is important to understand that development of dry valleys is a natural rather than a human-induced process, yet human activities play an important role in management of dry valleys. They can speed up or slow down the process of drying up of dry valleys. Reversion of dry valley development direction might not be possible. Right understanding of process of dry valley development is crucial for strategy setting.

In the past, most of the work has been carried out without due consideration of benefits of the local communities, which might have contributed to less progress of development work and restoring degraded dry valleys. What is needed is to start people-centered development programs. If farmers' problems of low income cannot be solved properly, dry valleys will be bound to further degradation. An important option is to reduce pressures on natural resources of dry valleys, because most of the human activities are concentrated in dry valleys. In doing so, the following considerations are suggested.

4.1 Socio-economic consideration and government policy

Since almost all the dry valleys are located in upland of many cities and better developed areas in China, management of dry valleys will have direct impact on these lowland areas. Government policy is needed to encourage lowland people who receive or enjoy environmental services of a good management of dry valleys to pay for the services. The payment should go directly to people of dry valleys to start off-farm activities.

4.2 Promoting renewable rural energy

Due to lack of other sources of energy, biomass is the main fuels in many dry valleys. As it is stated above, dry valleys in the Hengduan Mountains Region are characterized by low rainfall. Due to

severe environmental constraints, vegetation in dry valleys is extremely poor. Supply of firewood has been a big problem. In order to reduce local people's dependence on plants for fuel, renewable energy sectors should be promoted in dry valley. Except for micro-hydropower that has been adequately developed in many river basins in the Hengduan Mountains Region, use of solar energy for cooking and heating has not been promoted though most dry valleys are characterized by high solar radiation. In conjunction with drought in many dry valleys, solar radiation in many dry valleys is among the highest in the region. In particular, solar radiation in the lowest rainfall areas is the highest not only in the Hengduan Mountains Region but also among the areas with similar latitude (He Sudi & Wen Chuanjia 1983) and is among the high solar radiation regions in China (Zhang Jiacheng & Lin Zhiguang 1985). Unless local farmers are provided acceptable and effective energy options or they can afford to buy commercial fuel, conservation of natural vegetation in the dry valleys will become very difficult. In many cases, local people are always blamed for clearing vegetation as fuelwood. But few of us think what we have provided for them. None of us has tried to blame us scientists not being able to provide options to local people. Further, in the areas with high elevation, trees are very sparse, local people not only cut trees but also uproot grasses as fuel. Studies indicate that 85% of rural energy in a dry-hot valley is dependent on crop residues and wood (Ji Zhonghua *et al.* 2002), which has made it almost impossible to use crop residues to improve soil fertility.

Biogas is another potential sector. In many dry valleys, sufficient biogas can be produced throughout a year or at least for most time of a year. Promotion of biogas can not only meet partial requirement for energy, but also provide better organic fertilizers, which have confirmed by many studies. In addition, firewood plantation on marginal lands is another option.

Evidences have indicated that when farmers' incomes increase, they can afford to buy commercial fuel, such as cooking gas, the pressures on natural vegetation are automatically reduced. Cash crop based income generation activities, therefore, must be promoted because common food crops will not bring sufficient cash to farmers.

5 Development of niche-based cash crop cultivation

Dry valleys are climatic “enclaves” and agriculture should be targeted to develop niche-based sectors. It is essential to fully and correctly understand and assess the biophysical conditions of each dry valley before a practical development strategy is made. Research indicates that cash crops are the most important among the dry valleys that have been properly developed. Food crops play only a minor role in these dry valleys. In Maoxian of the upper Min River and in Miyi of the Anning River, for example, few food crops are seen in the really dry valley areas. Only cash crops and economic trees, such as vegetables, fruits trees, spice and aromatic plants and medicinal plants are cultivated.

Exploration of niche-based development sectors, with good international and domestic market potentials, should be carefully made with due consideration of full and sustainable use of local natural resources, active participation of local communities, sustainable local socio-economic development and environmental conservation. Global warming has brought about many changes and more changes in dry valleys are envisaged, which is needed to be taken into consideration. Research should be carried out not only for rehabilitation of degraded ecosystems alone, but also for advancing local economic development. Participatory planning and implementation of research and development programs should play an important role.

The dry valleys are characterized by “drying”, but the drying here is fundamentally different from the “aridity” in Central Asia and even the “aridity” in northwest China. Though dry valleys share many characteristics of arid regions in Central Asia and Africa, dry valleys in Southwest China are only

“conditionally dry”. The most striking difference is that there are enough water sources in the dry valleys of Southwest China that can be made available. But appropriate management is lacking. Availability of water resources is a striking comparative advantage over arid regions. In addition, different from the arid regions in Central Asia and other areas, the dry valleys of Southwest China are formed due mainly to geomorphological factors.

There are comparative advantages for developing niche-based cash crops in dry valleys but correct analysis is lacking. A literature review indicates that various cash crops have been cultivated in many different dry valleys. Improvement is needed to adopt a systematic and integrated approach for planning and implementation. Through development of niche-based cultivation mainly in river bottoms, pressures on most problematic slopes of two sides of dry valleys can be reduced. In combination with promotion of niche-based crops, appropriate measures needs to be explored to facilitate growth of herbaceous and shrubs instead of tree planting in restoration of degraded environment. In many dry valleys, any plants that can survive should be promoted. Tree planting might not be possible in many dry valleys. We need to think why do we continue something already proved impossible?

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