The restoration of sediment-related disasters and driftwood from national forest in Taiwan caused by Typhoon Morakot in 2009

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ABSTRACT: The number and area of new landslide, according to the interpreted SPOT images, caused by Typhoon Morakot in 2009 is estimated as 30,223 and 43,996 ha, respectively. The new landslide area in 2009 increased by about 16,392 ha in comparison with the landslide area in 2008. The heavy rainfall with a return period well over 200 years during Typhoon Morakot centralized in southwestern and southeastern Taiwan, and that also resulted in serious landslide disasters in national forest. Four forest working circles, including Chishan, Laonong, Pintung, and Dawu, are the most serious landslide zones with the landslide ratio over 8.0%. The Forestry Bureau assesses and ranks the seriousness of the disasters by using slope, the number of protected objects, the distance from the disaster to the protected objects to execute the restoration of sediment disasters and landslide in national forest. Due to the most torrential rain in the past 50 years caused by Typhoon Morakot, a large number of trees in the mountain area were destroyed. They became the driftwood, with a total weight of about 1.52 million tons, which ended up at the farmlands and ports. In order to recover agricultural products and livelihoods, Forestry Bureau made strategy for disaster prevention and reduction. Based on the strategy, Forestry Bureau sweeps away the driftwood by estimating its distribution, overcomes the issues caused by the heavy rainfall disaster, and helps the victims to recover their life.

KEYWORDS: Sediment-related disaster; Landslide; Driftwood

1. Introduction

The rapid global climate changes are causing intensive typhoons and torrential rainfall into normalization. Taiwan's national forests are mainly covered by forest vegetation and can reduce soil erosion in the normal condition. However, when continuous rainfall in a single 24-hour period exceeds 400 mm, forest land could become extremely prone to landslides. In addition, rock, soil, and wood carried by landslides often cause sediment-related disasters and massive deposits of woody debris. When Typhoon Morakot struck Taiwan in August 2009, rainfall exceeding 2,000 mm in many areas overloaded the capacity of forest vegetation, causing large numbers of landslides on national forest land. These landslides carried massive amounts of soil, and wood from slopeland forests borne along with the soil in the torrents caused by heavy rainfall yielded an unprecedented 1.52 million tons of woody debris, giving forestry personnel a severe challenge.

2. Landslides in National Forests

Following the Typhoon Morakot, images taken in cloudless weather by the FORMOSAT-2 (FSAT-2) satellite from August 8 to October 31 were used to determine the damage caused by the typhoon. After determining the area of land affected by landslides in areas under the jurisdiction of the Nantou, Chiayi, Pingtung, and Taitung forest district offices in the wake of Typhoon Morakot, the Forestry Bureau Aerial Survey Office found that the area of landslides increased from 13,786 hectares to 32,923 ha after the typhoon, which indicated that new landslides had affected an area of 19,137 ha. In addition, for all of Taiwan, the area affected by landslides increased from 22,696 ha to 48,605 ha after the typhoon, indicating a new landslide area of 25,909 hectares. Landslide survey work performed subsequently in 2010 and 2011 found that the area affected by landslides on land under the jurisdiction of the four forest district offices was 33,333 ha at the end of 2010 and 25,015 hectares at the end of 2011. Figure 1 shows the scope of landslide survey work in the Zhuoshui River District on a satellite image taken by FSAT-2. The areas of landslides in the remaining forest districts were obtained using the same method.

According to the results of these landslide surveys, the Typhoon Morakot indeed caused a large number of landslides on national forest land under the jurisdiction of the Forestry Bureau's Nantou, Chiayi, Pingtung, and Taitung forest district offices. According to landslide survey data in 2011, owing to the absence typhoons and torrential rainfall during that year, initial vegetation had begun growing on landslide areas, and natural restoration was consequently beginning. The Forestry Bureau is performing surveys.

Fig. 1 Satellite photograph and scope of landslide survey-Example of the Zhuoshui River District

3. Planning of Sediment Related-disaster Mitigation in National Forest Land

Most national forest land in Taiwan is located

along the Central Mountain Range, so the terrain is steep and streams are short and fast-running. As a consequence, and also because of the fragile geology, landslides are a natural phenomenon. Because whether landslide areas require remediation work must be assessed, the Forestry Bureau commissioned the use of satellite images to determine whether such factors as the rainfall, hydrology, ecological environment, preservation objects, relief ratio, geology, vegetation coverage, soil erosion, landslide ratio, debris flow torrents, flow section, historical disasters, land use, and various river training works within watersheds will affect the incidence and scope of flooding, landslides, and debris flow. Taking national forest watersheds as the subject of assessment, the seven assessment indicators of preservation objects, relief ratio, geology, vegetation coverage, soil erosion, landslide ratio, and debris flow torrents, as well as the foregoing assessment indicators, were used to determine finer assessment items and scoring standards, allowing the assessment of the risk of national forest sub-watersheds and scoring. The scores of different sub-watersheds were used to determine the priority order of remediation work in national forest sub-watersheds, yielding the following results:

3.1 Sub-watersheds requiring highest-priority remediation: Those sub-watersheds on the foregoing assessment table are considered to require highest-priority remediation if they have a total weighted score of at least 55 points. A total of 295 sub-watersheds were assessed as having scores of at least 55 points. However, if a sub-watershed had few points from preservation objects, contains a wildlife refuge, or contains no roads, its status was changed to a sub-watershed in need of remediation. Following assessment, the status of 153 sub-watersheds was changed to sub-watershed in need of remediation, and status of the remaining 142 sub-watersheds was designated as sub-watershed in need of remediation. In addition, a total of 25 sub-watersheds within the experimental forests of National Taiwan University and National Chung Hsing University were assessed as sub-watersheds requiring highest-priority remediation, giving a total of 167 sub-watersheds requiring highest-priority remediation; survey, planning, and river training works for these sub-watersheds will be completed as part of a mid-term plan (2012-2016) (Table 1).

3.2 Sub-watersheds in need of remediation: Sub-watersheds in need of remediation may have a weighted score of at least 55 points, implying that they should be assessed as sub-watersheds requiring highest-priority remediation, but have few points from preservation objects, contain a wildlife refuge, or contain no roads, or have a have a weighted score of less than 55 points, and are therefore considered to have a status of key remediation or general remediation sub-watersheds; however, if there are many points from preservation objects, a sub-watershed's remediation priority shall be designated rolling management, which implies that the Forest District Office with jurisdiction shall perform remediation according to need (Table 1).

3.3 Key remediation sub-watersheds: The key remediation sub-watersheds listed on the foregoing assessment table have a weighted score of from 55 to 50 points, and it is expected that survey and planning work will be completed within ten years as part of long-term plans (Table 1).

3.4 General remediation sub-watersheds: All general remediation sub-watersheds on the

foregoing assessment table have this status. These sub-watersheds have a weighted score of less than 50 points; their status may be adjusted in the future as their situation changes (Table 1).

Management office	Sub-watersheds requiring highest-priority remediation	Sub-watershed in need of remediation	Key remediation sub-watershed	General remediation sub-watersheds	Total (sub-watersheds)
Hsinchu office	10	16	5	69	100
Dongshi office	13	48	13	74	148
Nantou office	21	48	24	64	157
Chiayi office	43	40	14	38	135
Pingtung office	42	89	8	35	174
Taitung office	3	38	3	12	56
Hualien office	6	16	2	8	32
Luodong office	4	28	2	18	52
National Taiwan University experimental forest	19	3	4	4	30
National Chung Hsing University experimental forest	6	1	-	-	7
Total (sub-watersheds)	167	327	75	322	891

Table 1 National forest sub-watershed remediation status distribution table

4. **Landslide Countermeasure in National forest Land**

4.1 Remediation strategies: Within the overall disaster survey and planning design, survey, and monitoring will be performed on the ecological environment and landslides in national forest watersheds, and overall remediation planning work will be conducted to provide a basis for river training works.

4.1.1 With regard to watershed management and erosion control project construction, the remediation of upstream watershed areas in national forests will generally focus on achieving stability and control, and watersheds will be taken as the unit of remediation. Assessment will be performed on the basis of watersheds' preservation objects, relief ratio, geology, vegetation coverage, soil erosion, landslide ratio, and streams with debris flow potential, and the determination of remediation priority will also reflect current watershed status, including landslide survey results, past landslides, and state of remediation. Remediation work items include source remediation, landslide remediation, torrent remediation, sediment control facilities, emergency disaster remediation measures, and revetments and retaining facilities, etc. From a perspective of ecology engineering, the planning of watershed remediation work aimed at achieving water and soil conservation will take function, safety, ecology, and environmental scenery into consideration.

4.1.2 Appropriate sediment control facilities will be adopted as remediation measures addressing various changes in torrents, and will seek to stabilize and control the riverbed, prevent or mitigate torrent erosion, scouring, and bank landslides, stabilize gullies, prevent the expansion of erosion, effectively control sediment production and transport, and reduce scouring and bank landslides. Project implementation planning and design will take ecological conservation, the project as a whole, the content of the planning report, and landslide severity into consideration, and will be followed

by approval of the project and project control. River training works will include sediment control measures include slope stabilization, ground sills, and revetments intended to curb the downhill transport of soil, maintain the stability of longitudinal slopes, control scouring threatening the stability of forest areas, and prevent secondary landslides, achieving stream stabilization, gully control, torrent control, and debris flow prevention and control.

4.1.3 Precipitous exposed slopes, fracture zones, landslide scars, slippage zones, and other areas where revegetation and reforestation are unlikely to be successful will be handled through the use of foundation engineering for exposed ground, along with supplementary revegetation of landslide scars and drainage works. Apart from seeking to stabilize the landslide foundation and prevent secondary landslides, revegetation and drainage projects can also inhibit slope landslides due to scouring from concentrated rainfall or runoff.

4.1.4 With regard to emergency remediation and maintenance projects, because sediment from torrents on national forests land may severely obstruct flood drainage, threatening roads, bridges, public facilities, and public safety, emergency remediation projects will be implemented on an expedited basis. These emergency projects will clear accumulated sediment from stream beds, eliminate channel blockage, restore flood drainage ability, and reduce and mitigate soil loss caused by typhoons and torrential rains. Where existing national forests structures have been damaged, reinforcing or repair work will be performed. Furthermore, emergency clearing or remediation will be performed at places where new landslides have occurred. With regard to follow-up maintenance, forest district offices will regularly patrol completed watershed management, erosion control, and restoration projects, and will perform maintenance work when necessary to maintain the projects' functionality.

Fig2.1 Before removal of sediment from Toukeng Creek in Xinyi Township, Nantou County

Fig2.2 After the removal of sediment from Toukeng Creek in Xinyi Township, Nantou County

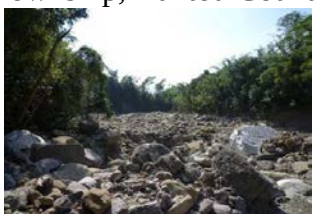

Fig2.3 Before emergency sediment removal from forest compartments 52 & 53 in the Yujing District, Dapu Township, Chiayi County

Fig2.4 After emergency sediment removal from forest compartments 52 & 53 in the Yujing District, Dapu Township, Chiayi County

Fig2.5 Landslide remediation project in forest compartment 39 near the Qishan River

Fig2.6 Completed lateral and longitudinal drainage project on landslide scar at 5K on Tengzhi Forest Road.

4.1.5 Remediation results: In the wake of Typhoon Morakot, funds from the Special Budget for Reconstruction after Typhoon Morakot were used between 2010 and the end of 2011 to implement 103 national forest watershed management and erosion control (watershed management and erosion control/hillside stabilization) reconstruction projects. These projects stabilized landslides covering 194 ha, controlled the erosion of 5.25 million cubic meters of soil, and mitigated landslide dams on the Taimali River (Taitung office), and Qishan River (Pingtung office), and Shiwen River (Pingtung office). The projects preliminarily achieved national forest watershed management and erosion control goals; subsequent work will be performed with funding from relevant project budgets. Figure 2 shows the results of sub-watershed remediation work in national forests.

5. Clean-up of woody debris

Article 15, Paragraph 5 of the Forestry Act states: "Following a natural disaster, when bamboo and wood is carried from a national forest to outside the national forest, the local government must complete recording of clean-up within one month; if a local government fails to complete recording of clean-up within one month, local residents may freely collect and remove the material." Accordingly, in order to clean up woody debris resulting from natural disasters and implement the drifting object clean-up response measures in Article 27, Subparagraph 14 of the Disaster Prevention and Response Act, on July 4, 2005 the Taiwan Forestry Bureau, Council of Agriculture called together relevant agencies and local governments for the purpose of determining the "Guidelines for the Clean-up of Woody Debris Resulting from Natural Disasters," which prescribe that the management agency or industry competent authority with local jurisdiction shall bear responsibility clean-up of woody debris, and establish a division of labor and standard operating procedures. The Guidelines have been forwarded to relevant agencies for implementation, and there are mechanisms for annual review and revision based on practical needs. Substantive rounds of review and revision were performed on June 21, 2007; July 14, 2009; May 20 and November 30, 2010; and June 27, 2011; see Table 2 for the assignment of responsibilities.

Location		Responsible unit
Within national forests		National forest management agencies
Reservoirs		Reservoir management agencies (organizations)
Rivers	Centrally-managed rivers	Emergency clean-up: River bureaus under the Water Resources Agency, MOEA Non-emergency clean-up: special municipality, county (city) governments

	Rivers managed by cities and counties	Special municipality, county (city) governments
Weirs		Weir management agencies
Seawalls	General seawalls	Irrigation facilities competent authority
	Industry-type seawall	Industry competent authority
Beach (shore)	Registered as a shelter forest	Forest District Office, Forestry Bureau
	Registered as under management of the National Property Bureau	National Property Bureau
	Designated a scenic area	Scenic area management office
	Designated a national park	National park management office
	Non-registered land	County or city government
Commercial port		Commercial port management agency
Fishing harbor		Fishing harbor management agency
Industrial port		Public or private enterprise with Ministry of Economic Affairs approval to invest in construction and management of industrial port
Military port, military beach		Military port management agency
Private land (farmland)		Special municipality, county (city) government; when necessary, assistance may be requested from a Forestry Bureau forest district office.

TABLE 2 UNITS ASSIGNED RESPONSIBILITY FOR CLEAN-UP OF WOODY DEBRIS RESULTING FROM NATURAL DISASTERS

Because the August 8, 2009 typhoon generated an unprecedented volume of woody debris, the clean-up process could not be limited to existing guidelines or procedures, but required the incorporation of disaster relief and mitigation thinking. The use of all possible methods in the clean-up campaign underscored the government's active, responsible attitude and sought to restore farming and production while the problems faced by affected residents. In view of the distribution of woody debris during the disaster relief period, the Forestry Bureau, Council of Agriculture (COA) consequently drafted the following strategies as part of the "Treatment Principles for Woody Debris Resulting from Typhoon Morakot":

5.1 Woody debris in fishing harbors

The first priority consisted of the clean-up of navigation channels, followed by clean-up of entire harbors. A total of 52 fishing harbors clogged with woody debris were distributed in 10 cities and counties, and included such major fishing harbors as Fugang in Taitung County and Yanpu in Pingtung County. Working 12 hours a day, navigation channels were cleared by August 18, enabling fishermen to get to fishing and restoring the transport of supplies to Lanyu and Green Island by ship. All woody debris was subsequently removed from fishing harbors, and any woody debris that floats into a harbor from offshore is promptly removed (Fig 3.1).

5.2 Woody debris on farmland

Because of the failure of major dikes, much woody debris was deposited on farmland. More than a thousand hectares of farmland in the Kaohsiung-Pingtung area was covered with woody debris, and the situation was particularly severe in Jiuru, Gaoshu, Wandan, Daliao, and Qishan townships. This woody debris had to be removed as quickly as possible in order to restore farming. In this type of situation, past operating procedures called for Forestry Bureau personnel to

first record the presence of any valuable wood and then remove all woody debris. In the wake of Typhoon Morakot, however, all woody debris was removed, regardless of whether it contained valuable wood that could be sold at auction, and piled at storage yards; the wood was then recorded and subsequent handling procedures implemented (Fig 3.2).

Early announcement of free collection and free use by private companies: After Forestry Bureau personnel complete recording any valuable wood, following the one-month deadline prescribed in theForestry Act, it can be announced that citizens could freely collect any unrecorded wood. In the case of Typhoon Morakot, after Forestry Bureau personnel recorded valuable wood on an expedited basis, early announcements were made of free public collection. Kaohsiung and Pingtung counties announced free collection on August 15, and Taitung County made such an announcement on August 20. In addition, apart from the early announcement of free collection, it was also announced on August 30 that private companies and manufacturers could freely remove wood of any size from areas designated by the local forest district office and could use the wood and woody debris in the manufacture of compost, pulp, or other items. All interested companies were allowed to call the local forest district number for permission.

Government subsidies encouraging farmers to clear their own land: The Forestry Bureau drafted the "Budget Measure for Subsidies to Farmers Clearing Woody Debris Resulting from Typhoon Morakot from Farmland," which provided a subsidy of NT$10,000 per hectare to affected farmers clearing their own land.

5.3 Woody debris in rivers

According to Article 76 of the Water Utilization Act, the river management agency must remove any woody debris threatening river control on an emergency basis. Based on the fact that large amounts of woody debris were deposited in riverbeds by Typhoon Morakot, and the Water Resources Agency undertook many river management reconstruction and dredging projects in the wake of the typhoon, the Water Resources Agency also removed woody debris when implementing these projects or clearing sediment. Town and township public offers were assigned to clean up woody debris lying in riverside areas after joint surveys by river bureaus, city and county governments, and forest district offices (Fig 3.3 & 3.4).

5.4 Woody debris in coastal areas

The government called on county and city governments, land management agencies, and industry competent authorities to clean up coastal woody debris, and made an early announcement of free collection. Encouragement of beach clean-up by volunteers: Because of the vast amounts of woody debris that washed up on beaches, the government mobilized volunteers to clean up beaches, and the Environmental Protection Administration charged local environmental protection bureaus to assist with transport and disposal.

5.5 Woody debris at sea

With regard to woody debris at sea resulting from Typhoon Morakot, because it had been announced that citizens could freely collect debris from affected areas, fishermen were also allowed to freely salvage wood. In accordance with the facts, the ownership of such wood was handled in accordance with Article 802 of the Civil Code, which prescribes finders' rights to ownerless property, or Article 810, which specifies the regulations concerning the collection of drifting objects.

5.6 Diversified use of woody debris

Usable wood

In accordance with the "Guidelines for the Clean-up of Woody Debris Resulting from Natural Disasters," woody debris resulting from natural disasters may be auctioned when determined to have auction value by the forestry competent authority.

6. Diversified utilization

Apart from small amounts of valuable wood such as red cypress, yellow cypress, and camphorwood, which could be sold at auction, the woody debris produced by the Typhoon Morakot consisted mostly of battered logs and scrap from trees with no particular commercial value. But although this wood lacked sufficient value for sale at auction, it could still be used for making furniture or pallets, as mushroom growth medium, boiler fuel, landscaping articles, or a sculpture medium. In view of these circumstances, the Forestry Bureau devised the following strategies to promote the diversified use of woody debris:

6.1 Village reconstruction

The Bureau's Taitung district office provided the affected Jialan Village with 140 tons of wood needed for home construction and 2,000 tons of woody debris subsequent village reconstruction projects. In addition, the Chant Oil Co., Ltd. donated NT$1 million specifically to assist Jialan Village construct demonstration homes and for the transport of woody debris and purchase of other building materials needed in the construction of a village meeting house. The company also worked together with the Taitung County governments and Jialan Village during the reconstruction period to plan and design demonstration homes and the meeting house. By combining the wisdom of Paiwan and Rukai elders with modern architecture and flexible applications, this campaign created village homes and a meeting house with an indigenous character, while expressing the traditional harmony between Taiwan's indigenous cultures and the natural world. Based on the experience acquired in the construction of demonstration homes, this Bureau continued to assist with the reconstruction of homes in other indigenous villages, and established architectural design drawing and standard construction process teams needed for subsequent home reconstruction work.

6.2 To assess the application of woody debris to the generation of biomass energy, Forestry Bureau held a conference with the Environmental Protection Administration to discuss the use of refuse derived fuel (RDF) and the feasibility of producing RDF from woody debris. At this conference, companies expressed that, because of current process, technological, and financial difficulties, as well as sales issues, this concept is not

feasible at present. In addition, the Bureau also commissioned National Chung Hhing University to study the economic performance of a wood gasification system. This research found that, as an example, a gasification furnace generating 5 million W in thermal energy would have a high power generation cost of NT$2.46 per kWh, and would require 8,100 tons of biomass annually. Since the power generation cost of this system would be higher than the wholesale cost of NT$2.0615 per kWh for biomass energy in Taiwan during 2010, it would not be economically efficient.

6.3 Driftwood carving art

The Forestry Bureau joined forces with Taipei National University of the Arts and other organizations to hold the International Driftwood Sculpture Festival at Guandu. Twelve foreign and domestic teams of artists were invited to create works of art from driftwood washed and scoured by the forces of nature. The artists produced 13 large works, including "Prayers for Blessings to Living Beings," "Devotion," and "Reflections on Driftwood." These works were displayed on Taipei National University of the Arts' Egret Lawn (Fig3.5to 3.8).

The Forestry Bureau also teamed up with the Council for Cultural Affairs and Taitung County government to jointly hold a series of activities forming the 2009 East Coast Driftwood Art Exhibition. These activities included a driftwood art activity, driftwood carving activity, photography contest, and the invitation of domestic master wood carver Wu Hsuan-san and other domestic and foreign artists (including those from Japan, Korea, Canada, and disaster-stricken areas in Taiwan) to jointly produce art giving the driftwood a new purpose.

The Forestry Bureau commissioned the Chinese Forest Products Association to hold the "Woody Debris Diversified Utilization Plan and Forestry Conservation Awareness Activity" and offer a wood carving training class providing training to 90 residents of disaster-stricken areas. The "Language of Wood" driftwood carving contest held on July 25, 2010 showed how woody debris could be given greater reuse value. A woody debris diversified utilization and creative design paper and results announcement conference held on November 16, 2010 featured talks on woody debris utilization technologies and product design approaches by speakers from academia and industry, and provided ideas for enhancing the value of woody debris.

Advanced high-temperature carbonization technology was used to transform woody debris into ecological charcoal used for deodorization, moisture adjustment, soil improvement, and water purification. The charcoal was also cleverly used as a creative material in installation art, showing how this material combines everyday life and art.

In order to make the best use of woody debris resulting from Typhoon Morakot, employing NT$10 million donated by the Chant Oil Company, the Forestry Bureau and Qinghua Online Cultural & Educational Foundation jointly implemented the "Plan to Use of Woody

Debris in the Development of Indigenous Cultural and Creative Industries in the Taitung Area." This plan established the "Xiangyang Xinchuan" woodworking workshop in a disused building at Duoliang Elementary School in Taimali Township, Taitung County, conducted training and production tasks, and established operating mechanisms creating jobs for indigenous residents. This plan can serve as a model for post-disaster reconstruction campaigns.

7. Outlook

National forest land is generally located in the upstream portions of watersheds, and the effectiveness of landslide remediation work will have a significant effect on overall watershed management and erosion control work. The Forestry Bureau will continue to implement national forest watershed management and erosion control in order to quickly stabilize forest land, nurture forest resources, prevent future disasters, and ensure green forests and clean water for future generations.

Although woody debris is a misplaced resource, it has cultural, artistic, and ecological value, is also an important cradle of biodiversity, and can play major roles in life, culture, and art. Through the diversified use of woody debris, community development, and village reconstruction, the Forestry Bureau has helped residents of disaster-stricken areas escape the shadow of Typhoon Morakot by reviving and building on traditional spirit and culture. In addition, the establishment of the Dongshi International Driftwood Carving Park shows how we should cherish our resources in the wake of disaster. Although woody debris has left the forests where it was created, it can be used to create new kinds of living value. When they visit this park, future generations will remember the suffering of those touched by the disaster and appreciate the Taiwan spirit of "transcending hardship."

Fig3.1 Gathering woody debris from Yanpu Fishing Harbor for shipment. Most of this wood consists of highly abraded tree trunks with the roots still attached.

Fig3.2 Woody debris in Xinfeng Village, Gaoshu Township. Most of the wood consists of trunks with attached roots, and there are no saw marks.

Fig3.3 Heaps of woody debris in Shuguang Park, Taimali, Taitung County. The roots are clearly visible.

Fig3.4 Recorded valuable woody debris consisting of trunks with the roots still attached and constituting national property. The roots have been abraded into irregular forms. (photo taken in Taitung City)

Fig3.5 Sun, Moon, and Stars—A work at the 2009 East Coast International Driftwood Art Festival

Fig3.6 Ball of the Earth—A work at the 2009 East Coast International Driftwood Art Festival

Fig3.7 Woodcarving -The New Beginnings

Fig3.8 Exhibit of creative items made by workworking trainees at the "Xiangyang Xinchuan" woodworking workshop