

Guantian agriculture wastes reused and energy recycled training program – Biochar of water caltrop shells



“Changing industry and consumption habits is the radical way to sustain farmland ecology.” Facing pesticide pollution, farmland ecology crises, the disposal and incineration of agricultural waste, rural talent outflow, and population ageing, Guantian District Office proposes a “quadruple development (4D)” vision to balance the livelihood, life, production and ecology developments in Guantian, in hope of changing the mode of agricultural production in Guantian so as to achieve the goal of sustainable agriculture, community care and development, and ecological conservation.

The Council of Agriculture (COA) has listed the pheasant-tailed jacana (*Hydrophasianus chirurgus*) as a schedule-2 protected species. The water caltrop farms in Guantian have become the important area for its survival. To prevent the recurrence of the mass food poisoning that killed a large group of the bird in 2009-2010 and to support the wildlife education of Guantian Jacana Eco-Education Nature Park, the Tse-Xin Organic Agriculture Foundation teaches local farmers to grow the water caltrop with eco-friendly methods and Guantian District Office even provides incentives to encourage water caltrop farmers to reduce using pesticide in order to reinforce pheasant-tailed jacana conservation and thereby strengthen agricultural eco-diversity.

Geographically, Guantian District is located at the center of Tainan City and occupies a total area of about 71 km², and most part of the district lies on the Jianan Plain. Demographically, the district has a total population of 21,535 people, with 3,511 people, or 16%, aged 65 or older. Climatically, the district has an annual average temperature of 25-29°C and annual rainfall of 1,000-1,273 mm. Agriculturally, the district has complete irrigation channels as it is the origin of the Jianan Irrigation System and surrounded by the Wushantou Reservoir, the Hulubi Reservoir, and the Wushulin Pond, making agriculture an important industry in the district. Major crops in the district include rice, water caltrops and mangos. The water caltrop is the most famous local crop occupying a farming area of about 237 hectares, commanding at 70% of Taiwan's total water caltrop growing area. In addition to the annual water caltrop output in Guantian is about 6,800 metric tons, there are 3,700 metric tons of wet water caltrop shells which are considered as waste. As water caltrop shells are hard, shaped, and difficult to decay and dispose, farmers often dump or incinerate them, thus causing sanitary problems and air pollution at the same time. Given in the "4/1000 Initiative: Soils for Food Security and Climate" ("4 per 1000" Initiative) advocated by the 2015 United Nations Climate Change Conference (COP 21) that "A '4%' annual growth rate of the soil carbon stock would make it possible to stop the present increase in atmospheric CO₂" (Ministère de l'agriculture, de l'agroalimentaire et de la forêt), and based on the circular business model from the carbonization of water caltrop shells, Guantian District Office began to promote relevant measures and action plans.

In 2016 the success of the circular business model was achieved by means of waste to resources: turning water caltrop shells into resources. This success was attributed to the equipment funding of the Tainan City Environmental Protection Bureau; the assistance of the Guantian District cleaning squad; the involvement of green conservation farmers, schools, and community volunteers and care centers; the collaboration of the biomass carbonization system training classes; and the consensus education of 2016 Guantian Water Caltrop Festival—Water Caltrop Exploration in Guantian and food and agriculture education of Guantian Junior High School. The product, carbonated water caltrop shells, was presented to local green conservation farmers for adjusting the acidity of the water caltrop fields and purifying water. With this product, local communities have even developed a number of by-products, including the deodorizing pack and water caltrop shells-biochar soap, to benefit community development and community care.

Collection of Background Data and Feasibility Assessment

In 2015 Guantian District Office introduced a simple technology for biochar production. At first, it attempted to build carbonization furnaces with abandoned gasoline barrels. After long-time testing and modification, Guantian District Office successfully developed a convenient and energy-free carbonization furnace for water caltrop shells. Later, it developed the dual-function cooking tun and clay furnace integrating heat recovery and biochar production using water caltrop shells and established the energy-efficient community kitchen. A field test was conducted on the biochar and vinegar produced from water caltrop shells. Guantian District Office also sent the biochar and vinegar to lab tests, including IBI, EBC, Taiwan's heavy metal, and other composition tests, to assess the feasibility and safety of the carbonization of water caltrop shells.

Co-Promotion of the Regional Circular Economic Development Plan with Public and Private Sectors

To develop a circular economy in Guantian, implement sustainable operations of agriculture and thereby to achieve the 4D vision, in 2016 Guantian District Office integrated public and private resources to build the carbonization system for water caltrop shells in order to promote six thematic strategies: sustainable environmental protection, agriculture value addition, enrooting food and agriculture education, community economic boost, co-learning and sharing mechanisms, and landscape esthetics creation.

1. Construction of a Water Caltrop Carbonization System

Through the co-design and co-development of the regional biochar system featuring local characteristics, high mobility, safety protection, heat recovery and easy operation, NCKU and a professional team have developed a standard carbonization furnace system, carbonization furnace cooling water system, and water caltrop vinegar extraction equipment equipped with a furnace top lid traction system, automatic cooling system, and an automatic revolving dispensing system to achieve easy operation and enhance operational safety. In addition, convenient management of system operation is achieved to enhance operational efficiency by monitoring air pollutant emissions in the production process with the air pollution control system and systematically monitoring system temperature with the temperature monitoring system. Different parameters have been trialed to confirm the moisture content of water caltrop shells in the carbonization process and the optimal operating conditions in terms of roasting time and roasting temperature. Then, after confirming roast evenness with visual inspection, water was poured on top to extinguish the fire

to complete the making of water caltrop shell biochar. The experiment found that every 15.0 kg of dried water caltrop shells can output 3.2 kg of biochar over a carbonization time of 30–35 minutes. A property examination of the water caltrop shell biochar found that BET surface area is 300-400 m²g⁻¹ and carbon purity is up to 70%, complying with the EU EBC and US IBI biochar certification standards.

The operating temperature of the carbonization furnace of water caltrop shells is 700-1,000°C. To facilitate on-site application with family furnaces and water caltrop furnaces featuring easy operation and high mobility, and assuming that all heat recovered from carbonization is used for cooking water caltrops in order to develop local industry, test results show that the heat for roasting six barrels of water caltrop shells equivalent to one can of 20 kg of liquid petroleum gas (LPG) can be recovered for cooking water caltrops. That is to say, the heat equivalent to 2,777 cans of 20 kg LPG can be recovered from roasting 1,000 metric tons of water caltrop shells for carbonization for achieving resources sustainable uses and developing alternative energy.

2. Field Test

Both domestic and foreign literature shows that biochar positively benefits soil, the environment, and agriculture. Therefore, the water conservation test, pot plant test, water purification test, and a field test were conducted on the biochar from water caltrop shells. The water conservation test found that mixing biochar from water caltrop shells in soil can enhance the water conservation, fertilizer conservation and purification functions. With the support and collaboration of Guantian Junior High School, Guantian Farmers' Association, and local farmers, private farmlands were provided for a large-area field test. Currently, there are five cooperative sites with a total testing area of 8,400 m² for growing crops including rice, water caltrops, peanuts, pumpkins, and guavas. The 2016 harvest found that the weight of water caltrops grown with biochar from water caltrop shells higher than that of the control group; the dry rice yield of the 5.0 m² of paddy fields with the biochar from water caltrop shells doubles that of the control group; the average plant height and ear length are 1.1 times more than that of the control group. Due to typhoon disasters, no yield was harvested in other experimental sites, and relevant tests will continue. In addition, four farms in Guantian and two farms in Pingtung County voluntarily joined the field test. Guantian District Office also held periodic farmer and expert consultation meetings for them to exchange and share the test experience and achievements.

3. Work Flow Establishment of the Water Caltrop Shell Carbonization

After confirming water caltrop shell carbonization technology and equipment construction, Guantian District Office integrated regional resources to develop a carbonization production model.

With 24.2% of citizens aged 65 or older, Balin is a community with the highest senior density in Guantian. Therefore, Guantian District Office and NCKU have co-developed comprehensive water caltrop shell biochar products. As water caltrop shell biochar has high porosity and strong adsorption capability toward small molecules, Guantian District Office and NCKU have transferred the technology to Balin Community for local volunteers and care center seniors have developed the local cultural and creative product “Guantian Black Gold”, a deodorizing pack, to promote community economic development. The production process of the deodorizing pack by senior citizens of the Balin community includes (a) shell collection; (b) shell drying; (c) shell carbonization; (d) cleaning and re-drying; (e) shell picking; and (f) manual packaging. Currently, housewives in Guantian District make deodorizing dolls with water caltrop vinegar; Daqili citizens make ceramic cups with the mixture of potter clay and water caltrop shells-biochar; Balin citizens make handmade deodorizing packs and soap; and Dongxi citizens dye fabrics and pendants with water caltrop shells-biochar. Then, the district office, local schools, temples and citizens sell the product. The profit from product sales is used to support the vulnerable groups and the meals and care of seniors in the community in order to revitalize the rural senior population together with the community, fuse the production of water caltrop shell biochar with local community life, and to develop the collaborative and mutual support life patterns in local communities.

4. Reducing Carbon Emissions and Effectiveness Assessment

The results of the 2016 water caltrop shell carbonization program found that 3700 metric tons of wet water caltrop shells can produce about 146 metric tons of water caltrop shell biochar. Based on the average carbon content at 73% of water caltrop shell biochar, the carbon solidification of water caltrop shell biochar is 107 metric tons. After deducting the carbon emissions of the carbonization equipment, air pollution equipment, cooling water equipment, and transportation, the net emissions reduced are about 375 metric tons CO₂e each year. In cost estimation, based on the regional carbonization equipment in this program, including peripheral facilities for collecting and testing relevant environmental parameters, the average operating cost is about 63.5 dollars for processing each metric ton of water caltrop shells and 117.5 dollars for producing each metric ton of water caltrop shell biochar.

A simple version of the carbonization furnace suitable for local uses will cost about 1,270 dollars. Although the actual benefits from yields increased from the reduction of pesticide uses will need a long-term evaluation, the positive benefits of this program are foreseeable, including local waste processing, recovery and recycling; the promotion of agriculture eco-biodiversity, environmental protection and sustainable development; implementation of community care and promotion of community economic development.

5. Training of Technicians for Carbonization Furnace Operation

To develop a model for learning together, sharing together, and using together in Guantian District and to enable farmers and citizens to make full use of the regional carbonization system in order to revitalize the agriculture and community economic development in Guantian District, a nine-hour carbonization furnace operation course will be planned and arranged with contents covering an introduction to the principles of furnace operation, the operation of peripheral equipment and systems, carbonization furnace operation training, and practice. With these contents, the course aims to equip farmers and citizens with a better understanding of the principles of operation and operating procedures of the carbonization furnace, and an assessment of the training efficacy will be arranged afterwards. Those who pass the post-training evaluation will be awarded with a certificate of pass to recognize their ability to independent operation of the carbonization system. In 2016, a total of five training courses were given for 24 trainees, including 21 passed the evaluation. In the future, Guantian District Office will plan and establish the Guantian District Biochar Nature Park Regulations, continuously organize operation technician training courses, and enable certified farmers and citizens to independently transport agricultural waste, operate the carbonization furnace, and proportionally exchange biochar products for use as soil amendments and inorganic fertilizers. In addition, a platform (e.g. LINE, FB fan clubs) for farmers to post their field test results will be established for exchanging and sharing experience and achievements in order to achieve sustainable environment and learning and sharing together. Guantian District Office also hopes that eco-friendly and sustainable farming methods can promote the transformation and increase the value of agricultural specialties in Guantian in order to achieve sustainable development for eco-agriculture.

6. Promotion of Education and Demonstrations

Based on the annual theme of “Befriending with Water Caltrops and Pheasants”, Guantian District Office organized the four-month 2016 Guantian Water Caltrop Festival in collaboration with community development associations, Wushantou

Reservoir Scenic Area, Tze-Sheng Temple, and the Pheasant-Tailed Jacana Eco-Education Nature Park. The festival included 17 topical activities and 20 exploratory activities, including organic water caltrop charitable sale, water caltrop culture and pheasant rearing exploration, water caltrop shell biochar promotion, water caltrop shell biochar soap DIY, eco-tours, and community excursions for visitors to understand more about eco-agriculture and local characteristics development and to grow hopes in visitors to support the promotion of sustainable agriculture in Guantian.

In addition, as a demonstration site for bio-carbonization system implementation, the team organized demonstrations to disseminate across Taiwan and to other agricultural towns, communities, and college and university students the promotion achievements and the concept of recycling agricultural waste into biochar for use in soil for a circular economy. In 2016 the team held a total of six comprehensive and interactive educational and demonstrative activities of different scales for up to 200 participants from Pingtung Agriculture College, community youths, and South District low-carbon demo communities. The team hopes to inoculate the sustainable ecology concept in participates and influence them to practice the concept in daily life and consumption in order to support eco-friendly sustainable agriculture.

7. Construction of Demo Sites for Low-Carbon and Sustainable Homeland

Guantain District Office and Guantian Junior High School have signed a memorandum of understanding (MOU) on food and agriculture education to build a test field of water caltrop shell carbonization, water caltrop shell biochar production area, and a heat recovery furnace on an area of 7,500 m² in order to build an outdoor biochar education park. By fusing with the Guantian Jacana Eco-Education Nature Park, Guantian Farmers' Association, and Guantian Community Development Association, food and agriculture education was administered in student group activity classes to encourage teacher and student participation. By doing so, the team hopes to inoculate the resource recycling and sustainable agriculture concepts in students through the power of education. In addition, Honest Farm in the district has offered 17.7 hectares of farmland for the field test of organic water caltrop shell carbonization. Guantian District Office also planned the Guantian Biochar Laboratory in an unoccupied space next to the district office to demonstrate the instruments and achievement posters of biochar promotion in Guantian District for demonstration and education uses, in order to reinforce the promotion of sustainable agriculture and environmental protection through dynamic and static courses. In the future, Guantian District Office will fuse with the outdoor biochar

education park, Honest Farm demo site, and nearby attractions, including the Guantian Jacana Eco-Education Nature Park and spots on Mt. Chunwen in Balin Borough, to build the green corridor landscapes in Guantian to promote regional tourism, eco-tourism, and the transformation and value addition of regional agricultural specialties to achieve the “4D” goal.

Da Ai Television- Reuse of water caltrop shells)

<http://daaimobile.com/desktop/news-detail.php?id=37497>

Da Ai Television- Advantages of water caltrop shell biochar

<http://daaimobile.com/desktop/news-detail.php?id=37508>

Public Television Service-Our Island-To lock the carbon

<https://www.youtube.com/watch?v=hJjBNqT745E&feature=youtu.be>