APP Thematic Feature No. 7

Intra-ACP Agriculture Policy Programme (APP) Caribbean Action, with funding by the European Union under the 10th European Development Fund (EDF)

Intra-ACP APP Caribbean Action

Improving 'greenhouse' technologies to grow safe, healthy foods, protected from the weather, is possible... even in the tropical Caribbean heat

96° in the Shade: Cooling Things Down in Protected Agriculture Structures

The Caribbean Region is known around the world for being hot. That is what brings flocks of tourists to its beautiful, sunny beaches when the whiles of winter hit other parts of the globe. But with a changing climate, the Caribbean is getting hotter, and that's not always a good thing. A warmer climate leads to rising sea levels, droughts and floods, new pests and diseases and other challenges that test the tolerance of our agriculture industry.

Metal greenhouses in Jamaica (Photo: Isratech Jamaica Ltd.)

While some may still think that 'climate change is a farce', the world's scientific community has generally concluded that climate change is happening beyond any doubt, and the evidence is there for everyone to see. The Caribbean is certainly seeing and feeling its fair share of the new realities of a changing climate. For Caribbean farmers, the not-so-pleasant unfolding climate changes are forcing them to examine their current practices and look for new ways of doing things in order to adapt to the new reality. At the same time, they must also reduce the environmental footprint left by traditional agriculture practices.

Change must also come to Regional systems responsible for food and nutrition security in the Caribbean. With a food import bill of approximately US $5 billion dollars a year, the Region cannot afford to ignore the impact of climate change on the global food system on which it has grown to depend on so significantly. And, it's not just about food for human consumption but also for animal feed and raw material for agro-processing. These realities demand that the Region take action to support the agriculture industry and strengthen its linkages to food production systems.

This feature provides an overview of Protected Agriculture (PA) structures as an important thrust to tackle increased food production in the Caribbean in a new climate reality. It provides background on the challenges experienced in adopting the technology and utilising traditional PA practices, and discusses various options and benefits from improving the design and operation of these structures. It introduces and highlights the elements and potential benefits for transforming farming systems in the Caribbean through the construction and operation of the Region's first tropical greenhouse created under the GIFT (Green Intensive Farming Technologies) project. This project is a collaborative effort of the Caribbean Agricultural Research and Development Institute (CARDI) and the University of The West Indies (UWI), under the Intra-ACP APP Caribbean Action. The APP is funded by the European Union under the 10th European Development Fund (EDF), with Inter-American Institute for Cooperation on Agriculture (IICA) as the executing agency, and CARDI and the CARICOM Secretariat (CCS) as implementing partners.

Is There A Need for Protected Agriculture Structures in the Caribbean?

This month representatives from around the globe will gather in Marrakech, Morocco for the United Nations 2016 Climate Change Conference. Discussions will center on how to slow the rate of change in our global climate. Farmers in the Caribbean may, or may not pay much attention to the news coming out of the conference. However, they certainly can't help but pay attention to the changes already happening which are affecting the conditions for farming and food production in the Region.

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Climate change has resulted in the warming of the earth's surface by 0.3 to 0.6 degrees Celsius since the late 19th century. The four warmest years on record have occurred since 1990 and the trend is not expected to stop. Warming temperatures have a number of side-effects: storms get stronger, powered by warming oceans; sea levels rising as warm water expands and glaciers and snow caps melt; precipitation patterns changing causing heavy rainfall and flooding in some areas and drought in others.

Insert Photo #2 - Landslide due to heavy rains in Saint Lucia, 2010
(Photo: Global Giving)

In its' 2002 report, The Caribbean Planning for Adaptation to Global Climate Change Project outlined some specific concerns for Caribbean territories. Antigua and Barbuda were noted for a risk of increase in the number of storms and hurricanes, as well as increased drought. In The Bahamas and Grenada, rising sea levels causing considerable land loss is predicted. Decreased rainfall in Jamaica and Dominica will affect fresh water resources and in St. Vincent and the Grenadines heavy rainfalls are expected to cause flooding and landslides.

Since that report, evidence of climate change is everywhere - from significant droughts in 2010 and 2015, to strange and powerful dry season storms - the Caribbean is feeling it. The immediate effects were recently seen in Haiti where Hurricane Matthew killed over 500 people. The less reported fact is that it also wiped out nearly 100 percent of crops in the Grand-Anse region.

Destruction in Haiti resulting from Hurricane Matthew, 2016.
(Photo: IICA, Haiti)

Agriculture is one of the most vulnerable sectors to the impacts of climate change. The powerful storms and higher storm surges that batter the Region, cause damages in the billions to the industry. All of this while at the same time food demand continues to surge.

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In order to be able to meet regional demands, agricultural output will need to increase by 70% by the year 2050. Farmers are the first line of defence in enabling the Region to meet this objective. However, in addition to several other challenges, including losing farm land to other economic activities, they now have to find ways to significantly increase food production while battling the destructive impacts of climate change.

"To respond to climate change is to pursue a path to sustainable development", says Dr. Michael A. Taylor, in his book "Why Climate Demands Change", published in 2015. "The demand is for sustained action which will build climate resilience through the mainstreaming of climate considerations into planning for development and the daily routines of Caribbean life." This includes the planning and routines in regional agriculture. In the Caribbean, it is time to become climate-smart.

For agriculture in the Caribbean, becoming climate smart means considering the increased use of green intensive farming technologies (GIFTs). GIFTs are technologies aimed at optimizing production, reducing environmental impacts, addressing environmental changes and creating sustainable farming systems in the Region. They offer an excellent opportunity for farmers to both adapt to the changing climate and meet increased productivity demands in the Caribbean. As noted by Dr. Ruel Ellis, a lecturer in the Industrial Engineering programme at the University of West Indies and lead engineer for the GIFT project, "GIFTS must lead to sustainable farming systems in the Region by providing the tools for farmers to adapt to changing needs and circumstances."

A major element in the application of GIFTS is Protected Agriculture Structures.

What is a Protected Agriculture Structure?

According to the Caribbean Agricultural Research and Development Institute's (CARDI) 'Tropical Greenhouse Growers Manual for the Caribbean', Protected Agriculture (PA) can be defined as "the modification of the natural environment to achieve optimum plant growth." PA structures can take a variety of forms, such as, greenhouses, tunnels, and shade houses. This feature will focus on mainly on greenhouses.

Greenhouse farming in Saint Lucia. (Photo: IICA Saint Lucia.)

Greenhouses should be sturdy, sustainable and functional. Traditionally, they are constructed with a wood or metal frame, and plastic is used for roof coverings, shade cloths and insect mesh. There are a wide-variety of plastics that can be used in the construction, each of which has their own benefits and drawbacks.

There are also a variety of structural designs from which to choose, which should be based on the environment where the greenhouse will be located. As noted in the CARDI manual, two distinct zones can be identified in the Caribbean. There are structures which accommodate low elevation, hot humid environments which are below 500m above sea level and have an average daytime temperature of above 28 degrees Celsius. There are also

Type of Plastic	Advantages	Disadvantages	Durability	Light Transmission
Acrylic	Weather and break resistant	Flammable, expensive and easily scratched	Very good > 5 years	Very good > 90%
Polycarbonate	Impact resistant, flexible and relatively inexpensive	Reduced light transmission with age, expands and contracts and easily scratched	Good Approx. 5 years	Fair to good 80 – 90%
Fiberglass	Impact resistant, moderately priced and easily cut	Reduced light transmission with age	Very good > 5 years	Fair 80%
Polyethylene Film	Inexpensive and variety of sizes	Requires maintenance and can puncture or tear	< 5 years	Very good if kept clean > 90%
Polyvinyl Chloride Film	Allows UV through and has heat retention properties	Requires maintenance and can puncture or tear	< 5 years	Good if kept clean >85-90%

Source: 'Tropical Greenhouse Growers Manual for the Caribbean', CARDI, January 2014

Best Greenhouse Designs for the Caribbean

- Tunnel (Arch)
- Single Arch (Raised)
- Gable and Split-Gable
- Split-arch

Source: 'Tropical Greenhouse Growers Manual for the Caribbean', CARDI, January 2014

structures that are better suited to cool, high elevations that are above 500m above sea level with an average temperature of below 28 degrees Celsius.

Important to the structural design are the:

- greenhouse roofs - most are built with a pitch or curvature to allow fast runoff of rain and simplified cleaning. A tall roof also provides a temperature air buffer zone, which is particularly important in hot climates.
- entrance doors - a double-door entrance should be created to provide an "airlock" and increased protection against pests, and an entrance porch can be added to provide protection against wind and the spores that it carries.
- ventilation – these considerations are also extremely important, especially in hotter climates.

Lastly, while not a 'design' issue, the location of the structure is as key to its efficient performance as is its design. Care needs to be taken when selecting a site for these PA structures. A producer must consider the environment, including wind flow patterns, sufficient light exposure, temperature and humidity, the slope of the land, as well as access to utilities, including power and water.

Can PA tackle the challenge of Climate Change and Increased Food Production in the Caribbean?

For Caribbean farmers, PA structures can be an effective tool in addressing both productivity demands and climate change adaptation strategies. PA structures require less space, addressing the problem of decreasing availability of good farm land, as well as provide protection against wind, excessive rain or intense heat, all of which are a result of climate change. Greenhouses, shade houses and tunnels can often yield up to ten times the output of open field systems and they utilize sustainable technologies and integrated systems to optimize the conditions for successful crop production, addressing the need for increased output.

Protected agriculture farming in Saint Kitts. (Photo: IICA Saint Kitts)

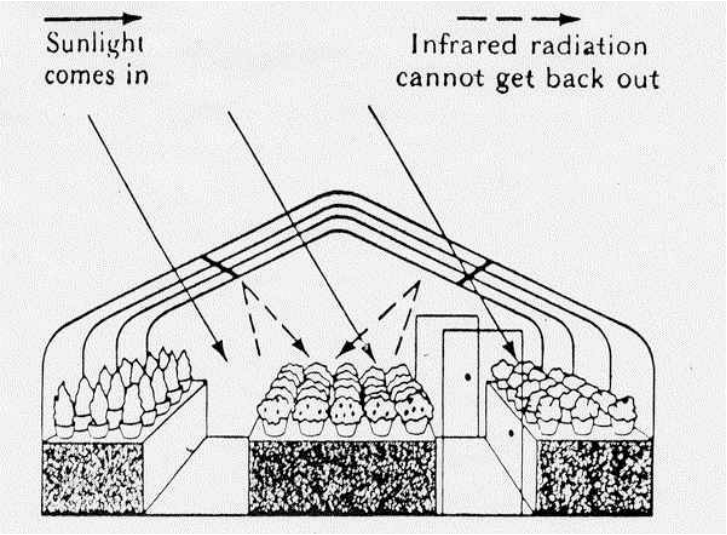
Greenhouses, due to their controlled environment, also allow for crop growth throughout the year, without the restriction of certain seasons. Crops can be warmed and cooled as needed to maintain a constant growing 'season'. They also allow for better control with respect to insects, light density, temperature and humidity. Use of fertilizers and pesticides can be targeted for more precise use and can be easily monitored and, problems such as runoff can be reduced. All of these factors lead to more efficient crop production. "Greenhouse production systems could present attractive returns on investment opportunities, possibilities for environmental conservation and marginal land utilisation", states the CARDI Greenhouse manual.

Benefits of PA Structures for Use in Caribbean Agriculture

- Require less space
- Protection against wind, heat and excessive rain
- Provide opportunity to grow crops year around
- Controlled environment – light, temperature, humidity
- Better insect control
- Targeted fertilizer use
- Reduced runoff
- Collapsible structures are available for use during weather events
- Higher yields

One of the problems in the Caribbean though, is that the structures are often fabricated in Europe or North America. According to Jervis Rowe, a protected agriculture specialist in his comments at a 2015 GIFT Regional Forum, when structures are brought in from elsewhere they are often entirely wrong for the Caribbean environment. He noted that this was a challenge that must be addressed in order to move forward with the use of greenhouses in the Region.

"We have good environment, such as the amount of light in a given day and the quality of water, but the main problem is heat within the greenhouses and as such some level of emphasis needs to be placed on getting these houses down to a temperature that will cause them to operate more efficiently", said Mr. Rowe.



Source: Green Intensive Farming Technologies: Agriculture Innovations in the Caribbean, Dr. Ruel Ellis, UWI, 2015

Too much heat in a greenhouse is not good. "By definition and design, the purpose of a greenhouse is to capture solar radiation and provide an optimum environment for the rapid growth of plants. However in the south, greenhouse temperatures often soar to levels that can limit plant growth", says Dr. J Raymond Kessler, Jr in his paper 'Dealing with the Heat in Southern Greenhouses '. "How much heat builds up during high-light periods depends on how much solar radiant energy is transmitted through the glazing, how that energy is distributed, and how much is retained within the structure."

Some of the detrimental effects of high temperatures in a greenhouse include reduced stem strength, reduced flower and leaf size, delayed flowering, early death of buds and reduced growth rates. All of these problems go against the whole purpose of these structures, which is to enhance productivity and protect against climatic harm. Without a proper solution, investing in fully enclosed PA technology won't make sense for Caribbean farmers and is often the reason why many PA farmers prefer to use 'shade houses'.

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Dr. J Raymond Kessler, Jr, 'Dealing with the Heat in Southern Greenhouses'

However, there are currently several solutions that are utilized in the Caribbean to reduce heat in greenhouses:

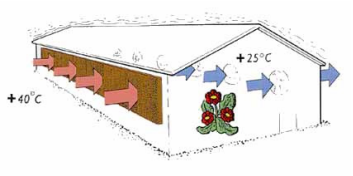
- **Proper Ventilation** - the role of proper roof design: To maximize natural ventilation there are a few good practices, as noted in the CARDI tropical greenhouse guide. A split roof design works best, forcing a pressure differential to extract the hot air at the top of the structure.
- **Structure Orientation** – the role of good location: The structure should be oriented to harness the most cooling benefit from prevailing winds and in a location where trees and bushes don't block the air coming in or out.
- **Construction Material & Design** – not all materials are equal or perform well in all environments: Proper research into material choice is key and experience has shown that use of high side walls and an appropriate mesh size that allows airflow, while still keeping out the bugs, yields relatively better results. Advances in technology allow for a wider option of material choices for the tropics than when greenhouses were first introduced in the 1980s.
- **Cost-effective Temperate Control:**
  - Extractor fans are the usual way to control temperatures in greenhouses. The size of the fan required will depend on the size of the greenhouse. However, one of the challenges, especially in the remote parts of the Caribbean, is that these fans require power. This isn't an ideal solution as it can be a significant cost for small farms and often rural locations are far from the power grid.
  - Wet walls are also common for temperature control but like extractor fans, they require power, as well as a constant supply of water. Wet walls operate on the principle of creating an air inlet into the greenhouse through a porous material that can be saturated with water. Wet wall systems are installed with a fan at one end and the wet wall at the other because the air

has to be drawn though the greenhouse with enough air speed to draw out the water, which evaporates in the greenhouse and provides cooling. Caution has to be taken to ensure that air cannot be drawn through other openings such as vents and doors, thus reducing the volume going through the wet walls.

- Swamp coolers can also be used. These are self-contained units that are usually used in smaller greenhouses. They have evaporative pads and a blower and are mounted on the outside, blowing the moist air in through an opening in the sidewall.

  Unfortunately, wet walls and swamp coolers can only work well when the humidity is low. The use of these cooling options under humid conditions will lead to too much moisture and therefore mold, fungus and other problems.

- Shade cloths or fabric also help to protect plants from direct sunlight. They offer a low-cost, effective solutions to ventilation and temperature control.



Source: Illustration of the cooling process of a wet wall
Dr. Ruel Ellis, UWI, 2015

Wet walls in use at a Caribbean greenhouse
(Photo: CARDI)

Improving PA Structures to Meet the Needs of the Caribbean

Research by institutions like CARDI and UWI, along with the on-farm use and adaptation of PA structures by expert practitioners, like Jervis Rowe, have shown that the 'protected agriculture' concept can be a viable, farming system choice in the Caribbean. The APP has incorporated education on and research into green farming technologies to contribute to building more efficient and resilient small holder food production systems in the Caribbean. Under Component 2 of the APP, CARDI and UWI have been working on a project to tackle some of the challenges that farmers in the Caribbean face when using PAs such as, high electricity costs, reliable access to water, high heat and too much humidity.

The GIFT Project, which is being carried out under the direction of UWI engineers in Trinidad and Tobago, is an innovative and integrated sustainable farming project designed to maximize the use of PA in the Caribbean, particularly in remote and off-grid locations. It combines many of the existing concepts used for cooling greenhouses, along with some new technologies and improvements to current processes, for specific use in tropical climates.

Installing underground pipes for cooling air and building the frame for the GIFT tropical greenhouse. (Photos: UWI & CARDI)

In traditional greenhouses temperatures can rise to as high as 50 degrees. For cooling, the GIFT tropical greenhouse uses the simple combination of passive ventilation and shading along with a ground-to-air heat exchange system. This system takes the air from the greenhouse and pumps it underground where the temperature in the test region is around 27 degrees Celsius. The trip through the pipes, about two metres underground, cools the air to around 28 or 29 degrees. The naturally cooled air is pumped back into the greenhouse, greatly reducing temperatures. In the trial GIFT tropical greenhouse, this is proving to be an effective system for addressing the problem of too much heat, as well as the problem of mold, which occurs when using wet walls for cooling.

Practicing aquaponics. (Photo: Michael Bowleg)

The GIFT tropical greenhouse structure will also install a rainwater harvesting system to feed an aquaponics set-up that is highly suitable for crop growth. Aquaponics grows fish and plants together. The fish waste provides an

organic food source for the growing plants, eliminating the need for environmentally harmful fertilizers. This factor allows for the resulting produce to be sold as zero or low chemical farming outputs, increasing its market value.

"People in Trinidad and Tobago are looking for green organic foods", says UWI GIFT project manager Akeim Ali. "This project provides the means to supply markets with food grown with little to no pesticide use." Dr. Ellis notes the significance of this fact. "If you eliminate chemicals you have a health benefit", he says. "No longer do we need to eat vegetables filled with unhealthy metals and chemicals that lead to future health problems."

To address concerns of power usage that can add significant costs to traditional greenhouses, all of the GIFT greenhouse systems will be powered using solar energy panels mounted on a local UWI-designed solar tracker, capable of following the sun to maximize solar energy intake. The solar energy is then stored in safe and reliable batteries which ensure constant operation of the GIFT systems.

Finally, remote monitoring of all GIFT systems is made possible over a secure internet connection. The GIFT user interface can be loaded onto a computer, tablet or smartphone, and the tropical automated greenhouse can be monitored and managed from any location. The project team is also working on remote control features which will allow the system operations such as, water levels in tanks, light intensity from the solar sensors and fans for the air pumps, to be controlled from a distance.

Though it sounds rather complicated and expensive, there are plans to make the GIFT system modular and scalable. The aim, says Dr. Ellis is "to make this a viable solution for the average Caribbean farmer". He is encouraged that it does not require any certificate for environmental clearance or regulatory permit approvals and should enable any person interested in zero or low chemical, intensive but sustainable food production in the Caribbean to begin operations in a very short timeframe.

This project addresses the issues that are being experienced by greenhouse farmers who want to use PA in the production of their crops", says Dr. Ellis. "It addresses the problem of too much heat, less land space for agriculture, the hassle of inclement weather and electricity and water costs. You can be totally off grid", he says. Not only that but "existing greenhouses can be retrofit to produce to their potential."

Are GIFTs the answer for the Caribbean?

Agriculture must change in the Caribbean in order to keep up with the currently unmet and growing demand for food, increased global competition and changes to our climate, not to mention the exorbitant regional food import bill. Traditional methods of farming must be examined and improved to adapt to new production and environmental realities.

Progress needs to include improved crop varieties, strengthened farmers' organizations, increased education and enhanced value chains, and work is being done under many development organizations in these areas. However, the use of PAs will also go a long way in progressing the industry and the introduction of this technology to youth is a good building block.

Growing peppers at the Charlestown Primary School Greenhouse in Nevis. (Photo: IICA Saint Kitts)

An excellent example of linking youth to innovation in agriculture can be found in St. Kitts and Nevis where students at the Charlestown Primary School are learning about the benefits of PA first hand. Three-hundred students can now anticipate a hot and nutritious lunch each day, using fresh vegetables grown by their own hands, partly in thanks to their new greenhouse.

The construction of the greenhouse was supervised by the Inter-American Institute for Cooperation on Agriculture (IICA) and funded by the New Zealand High Commission in Barbados. The project came about after a plea from the principal, who had seen the benefits of greenhouse agriculture being used by the Ministry of Agriculture in Nevis. She asked for IICA's help in bringing the technology to her school.

"It is anticipated that the greenhouse will help to reduce the cost of the school feeding programme and at the same time, the children will be exposed to greenhouse technology", stated Augustine Merchant, coordinator of the Delegation in St Kitts and Nevis.

The school has faced challenges to its feeding programme in the past related to the high cost of vegetables and other inputs, as well as the lack of local fresh products. It is hoped that this project will alleviate short term hunger and, in the long term, improve school attendance, reduce drop-out rates and improve academic performance and nutrition intake.

GIFT tropical greenhouse, under construction. (Photo: CARDI/UWI)

Initiatives such as these show the tangible benefits of protected agriculture, and the GIFT tropical greenhouse takes those benefits one step further. The GIFT tropical greenhouse solution is intended to provide significant economic returns while supporting environmentally responsible and sustainable practices and alleviating the challenges faced by the agricultural and food production system. GIFTS have also had the important side effect of pulling more young entrepreneurs into the business of food production because of the use of exciting new technologies.

The reality is that the Caribbean farming population is aging. The Region is in need of a new generation of passionate and innovative young people to secure the future of the sector. "GIFTs bring technologies people are encouraged by", says Dr. Ellis. He has seen younger people become excited about the use of technology in farming and he feels that it will catch on. And, though he acknowledges that it can often be difficult to introduce new technologies to farmers that often hold fast to traditional practices, he knows that the efforts to bring them on board will be worth it for both the agriculture sector, and the Region as a whole.

See also:

C2 Tech Feature #5- November 2016: 'Changing Climate, Changing Farm Systems'

C2 Tech Feature #6- November 2016: 'Are Farmers Still Planting by the Moon'

C2 Tech Feature #8- November 2016: 'Farming Green – Using Plant Material to stimulate crop growth and enhance animal health'

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