National Building Research Organisation

Newsletter

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Agricultural Decision-making and Adaptation to Precipitation Trends in Sri Lanka (ADAPT-SL)

Dear Readers

We are privileged to welcome you to this special edition of newsletter published on the progress of project implemented in collaboration with Vanderbilt Institute of Energy and Environment (VIEE) and National Building Research Organisation (NBRO).

Nearly 2/3 of Sri Lanka's population lives in rural areas and majority of them make a living directly or indirectly through agriculture. In spite of technological advances made on improved crop management, irrigation, plant protection and fertilization, weather and climate remain the key factors of agricultural productivity in any country. It is a well-known fact that annual rainfall in most part of Sri Lanka has shown neither significant increasing nor decreasing trend. Rainfall has become something that is difficult to predict and droughts and floods have become a common feature of the climate of Sri Lanka. Droughts and floods have made production of food crops difficult. Crop yield has dropped drastically compared to some years ago.

Considering this climate change phenomena NBRO and VIEE joined together and initiated the ADAPT-SL research to study the extent of current and future water stress experience of Sri Lanka under climate change scenario and the farmers' response to water stress. Further, the research team is also studying the variations exist across social, institutional and hydrological settings. Climate Research Unit (CRU) of NBRO is actively engaged in this study with the technical support of VIEE's experts.

This newsletter presents a diverse number of articles on the background and the different research and project works carried out during the research period. Hence, we enthusiastically invite you to read and enjoy this special edition of newsletter. Further, we warmly welcome your feedback and ideas to incorporate in our future activities.

Best Wishes,
Eng. (Dr.) Asiri Karunawardane
Director General, NBRO

The National Building Research Organisation and the Institute for Energy and Environment at Vanderbilt University have been collaborating on a research study to understand adaptation to climate change in the agricultural sector in Sri Lanka since 2010. Since our first visits, the project has expanded significantly in scope to include two more American universities and a much larger research team. The project has been funded since 2012 by the U.S. National Science Foundation. With NBRO's invaluable help, the US-based researchers have been interviewing and surveying paddy farmers in Sri Lanka's dry zone. Earlier in 2016, we completed the process of an initial survey of with 1500 farming households in 30 communities stretching from Vavuniya to Batticaloa to Hambantota. In January and February 2017, we will complete the process of interviewing these same farmers for a second time. Team members have also interviewed farmers and conducted focus groups, some of which included role-playing games.

The researchers have also been busy at work in the social sciences as well. Some preliminary results include the following:

- We have developed algorithms for accessing and analyzing data about vegetation health which have been generated from satellite images of the country. Where there is more rain, vegetation grows greener; where there is less, it becomes browner. These differences are visible from space, but Sri Lanka has a great deal of cloud cover. The team has developed techniques for dealing with this cloud cover and for using current data about vegetation health to make short term predictions about future climate health.
- A Sri Lankan national who formerly worked with the Ceylon Electricity Board is pursuing her Ph.D. in civil engineering at Vanderbilt. She is collaborating with several professors to develop models of water use in the Mahaweli system that look at different climate scenarios and how water may be allocated most efficiently to support drinking water, irrigation, and power generation needs.
- A student has been examining when major irrigation systems actually release water for planting in comparison to what planting dates minimize the amount of irrigation water a successful paddy crop will actually require. Initial results indicate that it is almost always more water efficient to plant crops sooner rather than delay water releases.

These and other results are being developed into papers, articles, and presentations (a complete list can be found at http://my.vanderbilt.edu/srilankaproject). In addition, many researchers will participate in a conference in Sri Lanka in July or August 2017, and we are planning outreach activities with policymakers and farmers.

In addition, VIEE is currently constructing a website to allow people in Sri Lanka to analyze data from our household surveys themselves. The website will be aimed at a technical audience, but users will not require any specific training in statistics in order to gain insights from it. The link for the website will be available at http://my.vanderbilt.edu/srilankaproject by early 2017.

The current funding for this work runs out in August 2017. However, VIEE and its partners will search for continuing funds to prolong and enhance the project.

Prof. George Hornberger
Director, Vanderbilt Institute of Energy and Environment

Cover Photograph
Image captured by Unarmed Aerial Vehicle (UAV) over Huruluwewa Tank, Anuradhapura.

Overview on ADAPT-SL

Mr. H. A. M. Dhamruwan
VIEE Project Manager, National Building Research Organisation

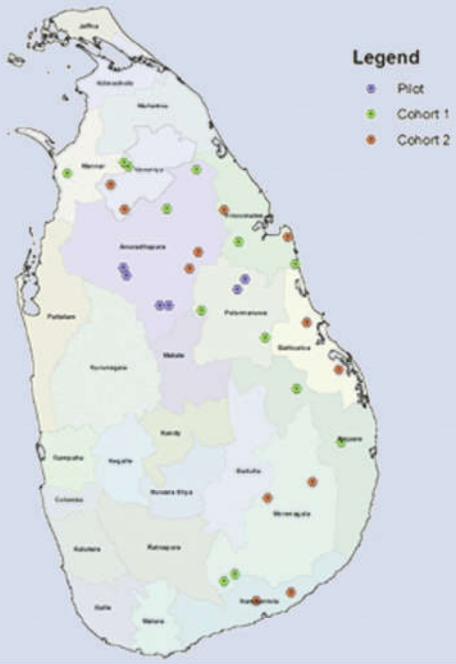
NBRO established a Climate Research Unit (CRU) in 2013, to conduct policy relevant research on climate change impacts and adaptation in Sri Lanka. Currently CRU researchers are mainly working on how vulnerable the small-scale farmers in Sri Lanka are, in the face of climate change on a collaboration research project of Agricultural Decision Making and Adaptation to Precipitation Trends in Sri Lanka (ADAPT-SL).

ADAPT-SL research aims to gain a better understanding of how farmers in Sri Lanka, in particular, are adjusting their practices to deal with climate change effects. Since 2010, researchers from National Building Research Organisation (NBRO) have partnered with Vanderbilt University' s Vanderbilt Institute for Energy and Environment (VIEE) in United States of America to examine the connections between agricultural adaptation and climate change in the dry zone of Sri Lanka, as project funded by US National Science Foundation.

Sri Lanka' s dependence on agriculture makes it particularly vulnerable to climate change. Much of the country' s attention in regards to climate change adaptation is focused on sea level rise, logical given the concentration of population and infrastructure along the country' s coast. However, further attention needs to be paid to inland areas. Temperature in Sri Lanka has increased about 1°c over the past 50 years, and is expected to continue to rise. While projections for rainfall are less certain, higher temperatures necessarily mean higher levels of evapotranspiration, suggesting that Sri Lanka may have less water in the future. The anticipated impacts of climate change are particularly problematic for the country' s dry zone, where agriculture is dependent both on rainfall and on water transported via canal over long distances. Farmers expressed that they are already experiencing changes in the onset and intensity of monsoon rains which make it harder for them to effectively manage their production and maximize yields.

In the above context, the ADAPT-SL project focuses on how Sri Lankan farmers have in the past and currently are adapting to climate change, and how they can adapt to future climate change in particularly in physical and hydrological, socio-economical, and policy domains through developing landuse maps, drought monitoring & forecasting methodologies, household surveys, crop modelling plans to water scarcity & etc.

Research area of the project includes 30 Grama Niladhari Divisions in 9 districts of the dry zone and across different irrigation systems and the project results and findings will lead to implementable changes that support farmers in the sustainable livelihood in the face of adverse climate change impacts.



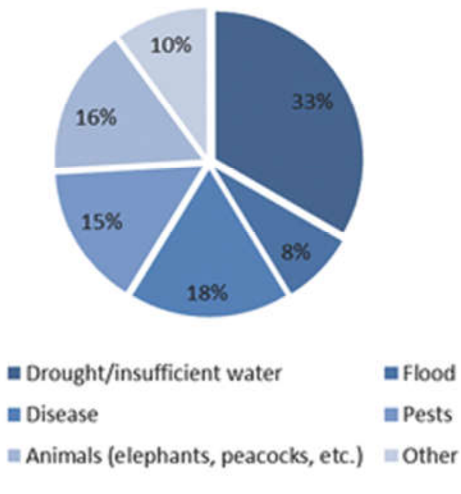
Sri Lanka Environmental and Agricultural Decision Making Survey

Mr. W. G. Winson Gnanatheepan (Climate Research Unit Coordinator),
Mr. S. Sutharshan (Scientist), National Building Research Organisation

The problems of managing water efficiently and equitably have become an urgent policy and a research issue in the recent years especially in the dry zone of Sri Lanka. The research study carried out by NBRO in collaboration with VIEE, Agricultural Decision Making and Precipitation Trends in Sri Lanka is aimed at finding out the factors affecting the disaster resilience of farmers living in the dry zone.

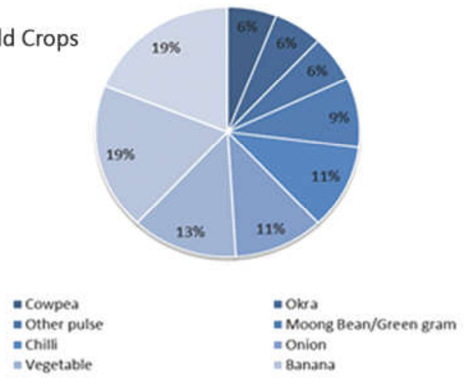
A household survey was conducted to identify the problems faced by farmers during their cultivation and to obtain baseline information on the socio-economic stratum of the targeted farmer communities. The research team has completed household (HH) survey in 13 farmer settlements around the island. This article presents the survey findings in brief.

- Reason for Crop Loss



Crop loss could be classified into two; production losses and post-harvest losses. Diseases, insects, weeds, other pests, animals and disaster annually cause substantial losses in the yield and quality of farmers' production in Sri Lanka. 1/3 of the interviewed farmers have indicated that drought and insufficient water as main reasons for their crop losses while 8% and 18% of the farmers have indicated flood and crop disease as main reasons for the crop losses. This survey has been carried out in 71.5 acre of farming land, out of which 48% are affected by drought while 16% are affected by animals.

- Other Field Crops

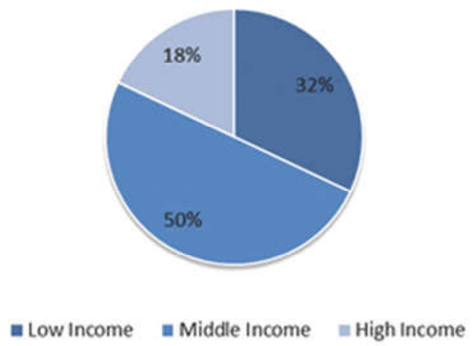


Banana (19%) and Maize (19%) are the major other field crops cultivated by farmers in their paddy land during off season as well as during drought period.

- Income Level

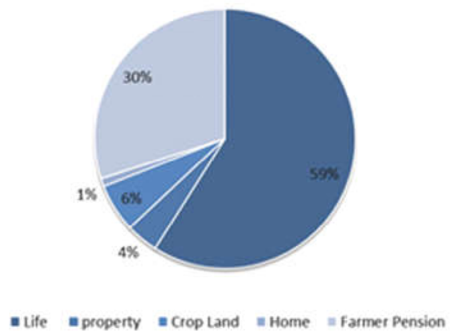
The Household Income and Expenditure Survey 2012/13 conducted by Department of Census and Statistics categorizes the income level as follows,

Income Level	Monthly income (LKR)
Low Income	below 15,750
Middle Income	15751 - 53169
High Income	Over 53,170



Half of the farmers living in the selected cohorts are middle income earners while 1/3 are low income earners. Among the farmers surveyed 55% depend on their farming income for their livelihood.

- Insurance



Developing agricultural insurance in line with international practice is critical to the sound development of the country's agriculture. Recent times, more parts of Sri Lanka have been affected by natural disasters. Every natural calamity or accident results in heavy losses of both life and property, seriously impeding the growth of the rural economy. But the country's current disaster relief system cannot compensate enough for such losses. Restoration of agricultural production after natural disaster requires a new risk-sharing and compensation system similar to agricultural insurance. Only 6% of the surveyed farmers have insured their crop land and 30% are getting farmer pension. Main reason for less insurance rate is that farmers' income is not stable and the cost of agricultural production increased at a speed that most farmers found difficult to afford.

According to the ADAPT – SL survey drought is an extreme event that limits the crop production. Disaster Management Act No. 13, 2005 identified 21 natural and man-made disasters in Sri Lanka and occurrence of drought is listed as the most frequent disaster.

According to the National Weather Service U.S. (2006) "drought is a deficiency in precipitation over an extended period, usually a season or more, resulting in a water shortage causing adverse impact on vegetation, animals, and/or people" .

The main consequence of drought is reducing the water availability in particular period over a particular area as reported by the Beran and Rodier in their study on Hydrological Aspects of Drought in 1985 for UNESCO and World Meteorological Organization. As the agricultural drought prevails in the country it leads to severe water scarcity in the dry seasons. The shortage of precipitation leads to low water availability in reservoirs and it results in the water shortage for irrigation lands and inefficient irrigation water management not only for the agricultural lands and also for various domestic uses and other needs.

To minimize the impact of drought on crop production, crop diversification can be implemented as a strategy to cope with drought.

As water availability is the main limiting factor, its influences on crop selection and OFC cultivation can be seen in water scarce areas (ADAPT-SL survey). Effective transition from mono crop to crop diversification can be achieved by applying crop models. There are many models to estimate the optimum solution for the crop mix for given constraints according to the literature. They are; gross margin analysis, inter-regional programming model and linear programming technique.

A linear programming model was constructed to obtain maximized profit among dry seasonal vegetable farmers with the constraints land, hired labor, fuel, fertilizer and seeds. In Huruluwewa irrigation scheme to provide an optimal crop plan to use the irrigation water economically the linear programming (by LINDO software package) approach was used for the given constraints land, labor, water and capital available in Yala season. The results showed that mono cropping is not economically viable and transform into multi crop production is a strategy of maximization of revenue.

The application of the model by farmers and their consultants such as agriculture extension officers will facilitate for efficient allocation of water and realistic estimation and analyses of costs, risks, and gains involved in diversified-crop farming ventures.

Crop Diversification: A Drought Resilient Farming Strategy for Water Scarce Yala Season in Irrigated Agriculture System

Mr. S.Sutharshan
Scientist, National Building Research Organisation

Agriculture system in Sri Lanka produces rice as its main form of product and it is the staple food of natives. Rice cultivation takes place mainly in the two seasons namely; Maha and Yala which are synonymous with the two monsoons. The cultivation is mainly done in low country dry zone during Maha season when there is sufficient rainfall. Farmers tend to cultivate other field crops in Yala season when water is scarce and farmers avoid cultivation when they experience extreme water scarcity or drought.

As a solution for drought and water scarcity and to make the water economically important for farmers, reservoirs had been constructed in Sri Lanka. During the Yala Season in 2013, 90% of irrigated land received water, whereas in the Yala season in 2014, only 58% received water from reservoirs. This clearly depicts the variability of water availability in Yala season.

Droughts impose negative consequences to agricultural production, and that has generated a necessity to build resilience into agriculture. Crop diversification can be implemented as a mechanism to cope with drought in a variety of forms, allowing farmers to choose a strategy that both increases resilience and provides economic benefits.

Optimal crop diversification plan can be devised by applying a Linear Programming model that is provided by LINDO software package to calculate the crop acreage, production and income. In order to get the maximum total income the constraints used to run the model are land availability, water availability, capital availability, maximum and minimum acreage. Water availability determination is an input to run the model in which the water measuring technique can comprises of irrigation canal calibration and water flow rate measurement. To allocate water for crops it is important to measure the crop water requirement for total growing period; it is feasible to measure by CROPWAT software by providing some inputs such as soil moisture content, evapotranspiration and some other parameters that are prompted by the software at the field level. Inputs of land and capital availability are almost constant for a single farming family and this information can be gathered by a survey. By providing these inputs into the Linear Programming Model it is possible to get optimal crop diversification pattern for specific arable land during a water scarce period.

Managing information for Complex Resilience Decisions

Dr. Shanaka Kariyawasam
Senior Lecturer, Deptartment of Town & Country Planning, University of Moratuwa

Community or collective resilience is a primary determinant of disaster preparedness of a settlement. Resilience planning and mitigation in this setting involve multiple stakeholders and perceptions from range of disciplines and places. Existing mitigation decision-making processes typically exhibit two main limitations. Firstly, techniques often feasibly accommodate only two dimensions at once and rely upon extensive use of assumptions. Secondly, they are cast narrowly and exclusively, as in either macro or micro, so simultaneously precluding both broader contexts and many details. Development decisions so informed are then based on partial information. Too often this has resulted in unsatisfactory outcomes for many groups of stakeholders along with increasing risk and heightened uncertainties.

Agricultural Decision Making and Adaptation to Precipitation Trends in Sri Lanka (ADAPT-SL) is an ongoing project of National Building Research Organization (NBRO), which is a collaboration of University of Colorado, Vanderbilt University, and University of North Florida. This project is a prime example on complexities in managing big datasets and producing informed decision information. Village profile is one of the outputs of the ADAPT-SL project which compiles social, economic, agriculture and livestock, disaster resilience, and infrastructure status of the a village. Data for the profile was sourced from a perception survey and a Community Action Planning Workshop that were conducted by the ADAPT-SL project as well as from the Grama Niladhari Division (GND) level census dataset. Simultaneously it was conducted drone based land use mapping, and optimal crop modelling exercises which enhanced the richness as well as the complexity of the profiling process.

The main objective of the village profiling was to provide decision information for a wider group of development partners. As different stakeholders concern on different aspects and criteria, the methodology adopted required providing of measures on a range of variables instead of single figure. On the other hand perception survey data set included big data set of 1,498 variables and more than 50,000 entries per GN division in different aspects. Therefore, this research adopted a perception mapping method (Desirability Matrix) based on the principles of Complex Stakeholder Perception Mapping (CSPM) (Kariyawasam, 2015) which provides both aggregated (aspect score) and disaggregated (Desirability matrix) information as per the choice of the decision maker.

The Desirability Index developed, organises all the potential attribute levels under each criterion in a finite grid space. Since these features are artificial objects drawn in an ordinal grid space, it has the advantage of positioning them in the order of "most desired" attribute level to "not desired" attribute level under each criterion. Since attributes locate themselves in a hierarchical order in the grid, it provides the flexibility of including another dimension into the process. According to this flexibility, this process allows the presentation of the intensity of stakeholder perception at each desirability level under each criterion as similar to CSPM. Each cell in the grid represents intensity of stakeholder perceptions (I_{ij}) at a particular attribute level (i), under a particular criterion (j) of the community.

Community perceptions collected through the perception survey were organized into different desirability levels based on general standards of each criterion as per the Table 1 (example only for Social status aspect). For quantitative data without standards, total frequency distribution was equally divided into 5 intervals. For example, criterion like paddy productivity where standards classification is not available, total range of the frequency distribution (0 to 40 bushels per acre) was divided in to 5 equal intervals from highest productivity (Most desired) to lowest (Not desired).

Table 1– Definitions for the Desirability Matrix Criteria

Aspect	Criteria	Desirability level				
		Most desired	Desired	Moderately desired	Less desired	Not desired
Social status	Social Stability	Traditional people	Newly settled	Resettled	Displaced	Encroachers
	Social wellbeing (happiness ladder)	9 to 10	8 to 7	5 to 6	3 to 4	1 to 2
	Level of Education	Degree/Diploma	Passed A/L	Passed O/L	Primary Education	No schooling

Any clustering around not desired level with high intensity indicates that there is a problem or need to be addressed by potential development partners (Farmer Organizations, National Building Research Organization (NBRO), Local Authority, Grama Niladhari, Divisional Secretariat, National Water Supply & Drainage Board, Mahaweli Authority, Irrigation Department, Non-Governmental Organizations, etc).

Sample of the Decision Index is shown in Table 2 for the Social Status aspect of the study. Since social stability levels are in a poor status with 77% of families are at a not desirable level (encroachers) it is shown in red colour. 24% of families are at a better position (permanently reside with freehold ownership) in terms of social stability.

Table 2 – Sample Decision Index

Aspect	Criteria	Desirability Index				
		Most desirable	Desirable	Moderately desirable	Less desirable	Not desirable
Social status	Social Stability (HH_I)	24			6	71
	Cooperation in Farmer Organization' s activities (SAT1_3)	77		24		

In summary Approach generates rigorous information to facilitate multi stakeholder decisions on both micro and macro level of village environment supporting strategic decision to advance community resilience and reduce risk in a collective manner.

References

Kariyawasam, S. (2015). Re-evaluating Local Economic Development in Sri Lanka: A strategic infrastructure evaluation framework to facilitate the development of regions. (Doctor of Philosophy Dissertation), Queensland University of Technology, Brisbane.

Community Action Plan - Shafinagar, Muthur, Trincomalee

Mr. W. G. Winson Gnanatheepan (Climate Research Unit Coordinator),
Mr. S. Sutharshan (Scientist), National Building Research Organisation

Introduction

The Community Action Plan (CAP) is one of the participatory tools used to build the capacity of community members in taking action in accordance with the problems, needs, and potential of the community. The CAP is a road map for implementing community change in facing their problems by clarifying what will be done, who will do it and how it will be done. The plan describes what the community wants to achieve, what activities are required during a specified time period, what resources (money, people and materials) are needed to be successful. Community considered as the center and primary resource of the CAP process rather than the objects of development. In this process, this approach motivates the project target groups to take the lead in the planning and implementation of project activities. Enhancing the resilience of rural farming communities is a major objective of the ADAPT-SL Project implemented by NBRO in collaboration with VIEE.

Target Area

The Shafi Nagar minor irrigation system which is under the purview of the Agrarian Services Department was selected for the CAP process. Shafi Nagar farmers depend on rain fed cultivation and they are facing difficulties in cultivating during dry seasons due to water scarcity. The GN was originally occupied by Muslim people who started to settle by 1960. During the war they migrated to nearby areas and they started to resettle in 2008. There are five villages in Shafi-Nagar GN division with about 300 families.

The primary occupation of these families is crop farming. They do the farming activities in Maha only (Rain fed). During Yala (Non- rainy season) some tend to cultivate green gram, maize and ground nut in small amounts and most of the people engage in other economic activities such as daily wage labor, maintaining livestock etc.

224F Shafi-Nagar GN division of Muttur Divisional Secretariat Division of Trincomalee district was selected as one of ADAPT-SL research sites in the category of minor irrigation agricultural settlements which cultivates under rain fed conditions (Maha only).

Target Group

The target group of the workshop is the members of the Farmer Organization as they are the persons who are directly affected by farming issues and have knowledge on institutional management.

Group Activity

Participants were divided into three groups.

01	**PRE**	Members of this group identified the problems they encounter before commencing the farming especially related to land preparation, crop planning, seed paddy etc.
02	**MID**	Members of this group identified the problems that farmers encounter during their cultivation especially related to water and disaster issues, fertilizer application, animal invasion etc.
03	**POST**	Members of this group identified the problems they encountered during the post harvesting stage especially related to storage, marketing, etc.

Outcome

Identified Problems and Solutions

Prioritized Problems	Identified Action
Water scarcity - unable to cultivate about 600 acre land	*Need irrigation canals from Neelaappali to 14th and 15th units Length 3.5 km*
Flood	*Provide flood mitigation bund from Sambadaru to Vethath-theevu*
Transport issues - Provide a boat to cross rivers to access agriculture land	*Provide a boat to travel from Safinagar to Vethath-theevu area (can cultivate extra 300 acre)*
Poor transport facility - Agricultural roads need	*Agricultural roads need rehabilitation and need boat to cross the river*
Transport issues - Need a bridge across the river between Vethath-Theevu and Safinagar villages	*Provide a bridge across the river (Ibrahim river) to connect Vethath-theevu and Kasimedu the specific point (in Safinagar) (40m length and 4.5 m width)*
Rehabilitate irrigation infrastructure	*Provide 60m canal to connect river and irrigation canal to Vethath-theevu*

Geo-spatial Mapping with Unmanned Aerial Vehicle (UAV) or Drone Technology

Mr. Kasun Ekanayake, Scientist, National Building Research Organisation

National Building Research Organisation (NBRO) in collaboration with Vanderbilt Institute for Energy and Environment (VIEE), USA is conducting a research study on Agricultural Decision Making and Precipitation Trends in Sri Lanka (ADAPT-SL) focusing especially on adaptation trends in the dry zone of the country. 24 Grama Niladhari (GN) Divisions have been selected for the research study covering Vavuniya, Anuradhapura, Trincomalee, Batticaloa, Monaragala and Hambantota Districts. Geo-spatial/ Landuse maps showing of each and every canal (Main, Branch, Diversion & Field) in agricultural areas, agro-wells, other land uses and buildings, should be prepared for each GN division for the identification of agricultural areas and water availability of major & minor irrigation systems in the study area.

At present, free satellite images and google earth images are used when preparing geospatial maps. But, these images have certain limitations. The free satellite imagery provided by Global Land Cover Facility are either lower or medium in resolution and they cannot identify the types of landuse very clearly. There is an option to purchase high resolution images. However the purchased images may not be the latest. Google earth imagery also have similar limitations. Further it is time consuming to obtain high resolution images, and it is necessary to use many applications for aligning and georeferencing the images.

To overcome these limitations, the best alternative solution is to utilize Unmanned Aerial Vehicle (UAV) or Camera Drone to obtain images and process them to obtain clear view of buildings, roads, cultivations, canals and other landuse patterns. Using a Drone can vastly reduce the time spent for collecting accurate data. It is possible to acquire raster data from the sky in the form of a geo-referenced digital aerial images, with resolution as sharp as 5cm per pixel. Following figures show the differences in resolution between google image and a drone image of the same area.

Drone Image of Pavatkulam area

Google Image of Pavatkulam area

NBRO owns a camera drone (DJI Phantom 03 Pro) and it is capable of making images for sophisticated mapping. Following steps are used for preparing geo spatial maps by using the drone.

Typical Drone Mapping Workflow

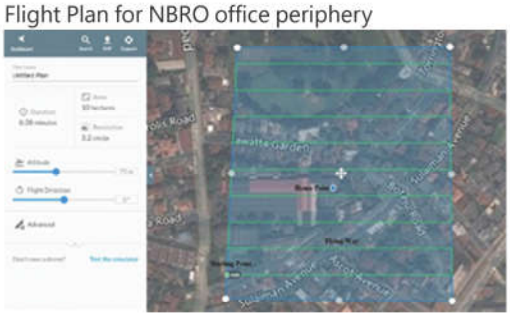
1. Flight Planning

Planning a mapping mission takes into consideration several factors,

- Whether to use Autonomous control or Manual control
- Whether no drone zones or other restricted areas lie in the flight path (e.g.- Airport)
- Identify obstacles in the area; especially transmission lines and towers
- Flight altitudes - this altitude determines maximum single flight coverage possible
- Image overlaps - this decides the number of images, hence the degree of resolution.
- Define safe landing point

In geo spatial mapping, the drone uses autonomous control plan by using related flight control applications. Flowing figure shows the flight plan created using DroneDeploy application.

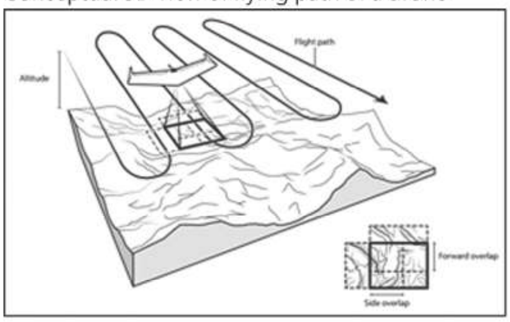
Flight Plan for NBRO office periphery



2. Flight and Import image

Next step is to fly the drone to get ground images as per the flight plan. The on-board SD card contains captured images and flight log. These images are geo-tagged according to flight log during importation.

Conceptual 3D view of flying path of a drone

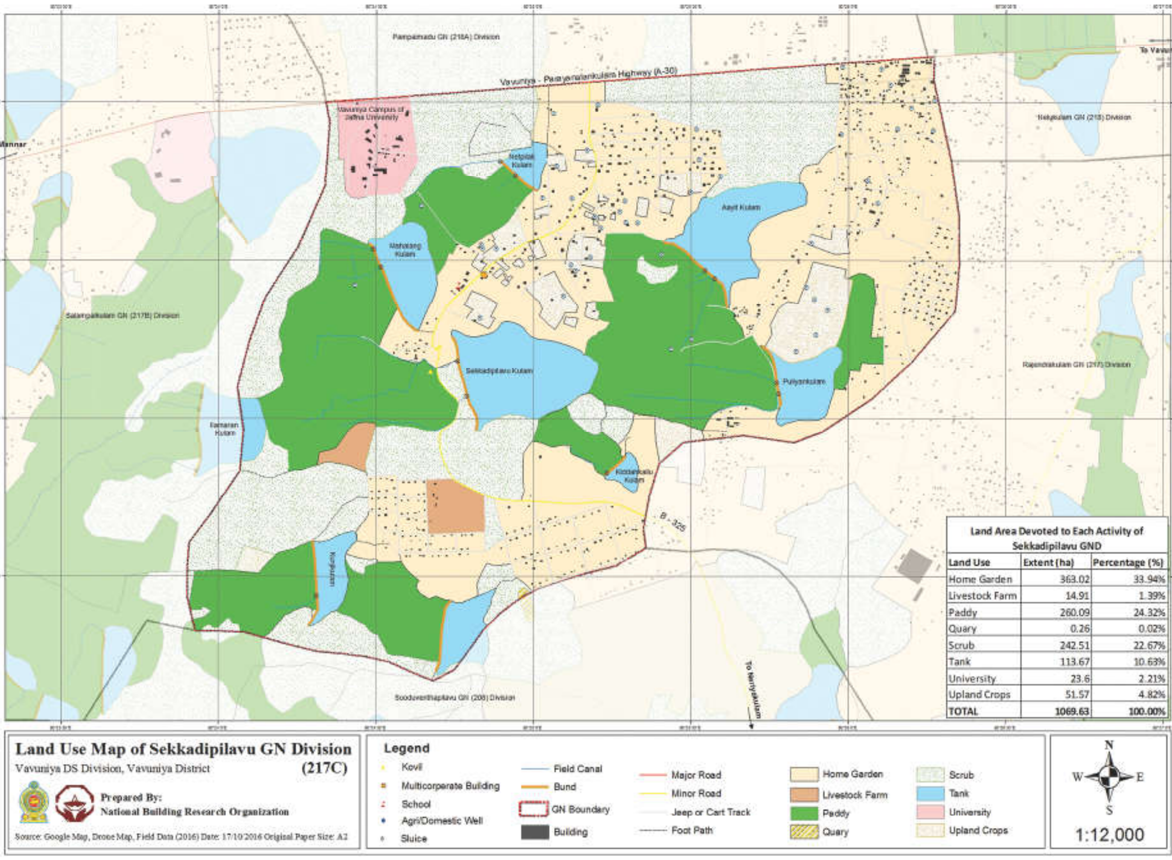


3. Generation of orthomosaics and 3D point cloud

Collected imagery are processed in a computer to generate a map. Currently, NBRO owns Agisoft PhotoScan software for processing the drone images which is capable of generating Orthomosaics and 3D cloud points.

4. Geo-Spatial Map Preparation

Images captured by drone can be used to prepare geospatial maps efficiently by using ArcGIS software. Presently, NBRO use UAV/ drone technology for landuse mapping and NDVI mapping for selected 24 GN divisions under ADAPT-SL project. Drone imagery can be used for landslide hazard mapping activities on 1:5,000 scale, 3D modelling of landslides and generating contours based on DEM. Further, this drone can be used for the 1: 100 scale mapping activities also.



Land Area Devoted to Each Activity of Sekkadipilavu GND		
Land Use	Extent (ha)	Percentage (%)
Home Garden	363.02	33.94%
Livestock Farm	14.91	1.39%
Paddy	260.09	24.32%
Quary	0.26	0.02%
Scrub	242.51	22.67%
Tank	113.67	10.63%
University	23.6	2.21%
Upland Crops	51.57	4.82%
TOTAL	1069.63	100.00%

Forecasts of Agricultural Drought in Sri Lanka

Thushara Gunda, George M. Hornberger, and Jonathan Gilligan
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Background

- Over ½ of agricultural crop damage in Sri Lanka is due to drought.
- Rainfall patterns divide Sri Lanka into 3 climatic zones: Wet (>2500mm), Intermediate (1750-2500mm), and Dry (<1750mm).
- Palmer Drought Severity Index (PDSI) has shown promise for correlating with Agricultural metrics from the disaster management information system, DesInventar[1]
- Climate change is expected to increase the frequency and severity of drought in the country but thus far, forecasts of future PDSI have been absent.

Research Questions

- How do PDSI forecasts for the future compare to historical PDSI in the country? Specifically, relative to the past:
- Will drought be more prevalent?
- Will drought severity increase?
- Are the drought patterns spatially different?

Figure 1. Thirteen meteorological stations used in analysis. Adapted from [1].

Methods

- PDSI is calculated with MATLAB tool[2] that conducts a physical water balance of precipitation, evapotranspiration, recharge, and runoff.
- Two 40-year PDSI datasets were developed For 13 sites:
  - Historical: 1967 - Future: 2017-2057
- Historical PDSI dataset was constructed with temperature and precipitation data from meteorological stations (Figure 1).
- Future PDSI dataset was constructed with dynamically-downscaled climate model projection data from regional circulation model, RegCM4 V2[3]

Note: RegCM4 V2 data show a bias towards lower temperatures and higher rainfall than historically observed at the meteorological stations.

- The following techniques were used to compare historic and future drought data:
  - Frequency and trend analysis to compare drought prevalence and severity
  - Principal component (PC) analysis to compare spatial patters of drought

Results

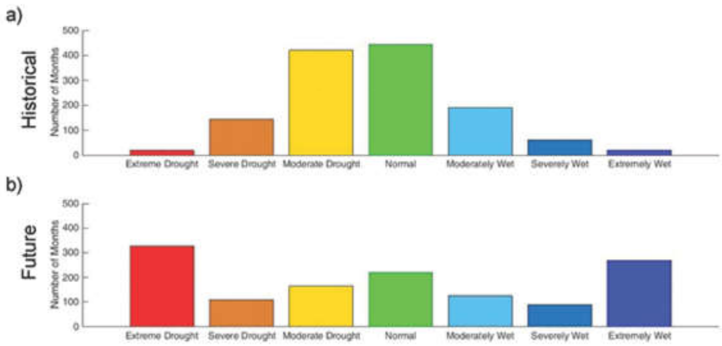

Figure 2: PDSI classifications for all 13 stations across Sri Lanka for a) Historical and b) future periods. Relative to historical conditions, there is a higher frequency of both extreme drought and extremely wet periods in the future.

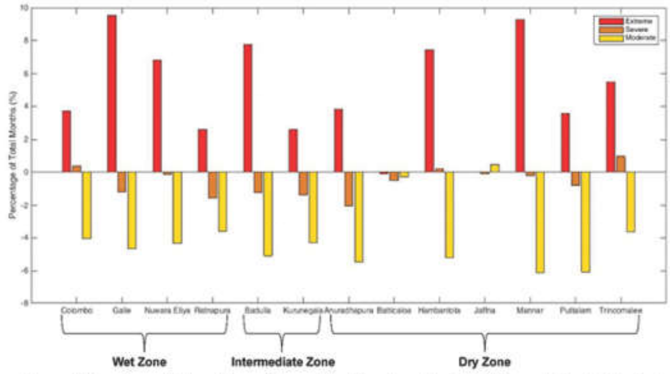

Figure 3: Prevalence of drought conditions at the 13 meteorological stations relative to historical conditions: Positive percentages indicate higher frequencies in the future and vice versa. Across all 3 zones, a higher frequency of extreme drought is forecasted for the future.

Table 1: Overall trends in PDSI for historical and future time periods; significant positive (i.e.,wetter) and negative (i.e., brier) trends are in blue and orange respectively. Many of the wet and intermediate zones were getting drier in the past while only Anuradhapura in East forecasted to become drier in the future.

Zone	Station	Historical trends	Future trends
Wet	Colombo	+	+
	Galle	-	+
	Nuwara Eliya	-	+
	Rathnapura	-	-
Intermediate	Badulla	-	+
	Kurunegara	-	-
Dry	Anuradhapura	+	-
	Batticaloa	-	+
	Hambantota	-	+
	Jaffna	+	+
	Mannar	+	-
	Puttalam	+	+
	Trincomalee	+	-

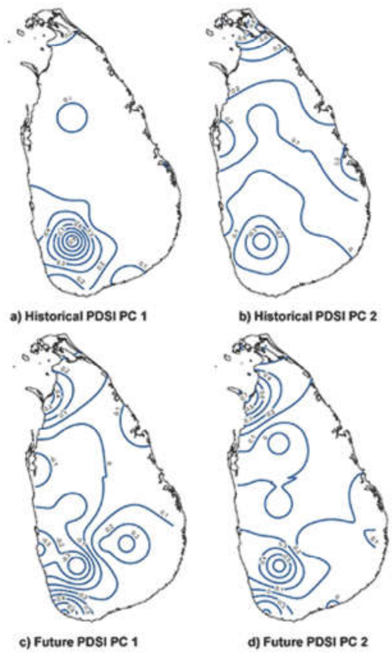

Figure 4: Un-rotated contours of loadings of the first two PCs for historical and future PDSI datasets. The first two PCs explain 68.5% and 71.4% of the historical and future variants, respectively.
In the historical dataset, PC 1 is in phase while PC 2 is out of phase. Thus PCs I and 2 correspond to the major and minor monsoons in Sri Lanka, respectively [1].
In the future dataset both PCs are out of phase and there is greater variability (i.e., more contours) across the country. Further analysis is needed to determine the physical implications of the shift in spatial patterns.

Discussion

- Relative to the past, PDSI constructed from the RegCM4 V2 climate data indicates that drought in Sri Lanka will be more prevalent and more severe across all 3 climatic zones in the country (Figures 2 and 3)
- Relative to the past, the wet and intermediate zones will no longer be becoming drier (Table 1) but autocorrelation influences on trend analysis is needed to verify results.
- Relative to the past, spatial patterns of drought are different (Figure 4) but further analysis is needed to understand the physical interpretation of these difference.

Next Steps

- Study autocorrelation patterns in PDSI datasets
- Assess monthly contributions and communalities of PCs
- Repeat analysis with bias corrected climate projections
- Analyse additional climate model projections

Forecasting Agricultural Productivity with Remote Sensing and Machine Learning

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Challenge: Provide high resolution drought monitoring and prediction tools in data scarce regions

Predictive tool applies machine learning to globally available MODIS datasets to estimate future changes in vegetation health at 250-meter resolution. The tool is global in coverage and the data, core software and software dependencies are completely free and open source. Tested in tow location with distinct agro-ecologies, climates, and levels of cloud cover (Fig 2): Sri Lanka and the San Joaquin Valley in California (Fig 1). Compared model performance with four sets of predictor variable (Fig 3).

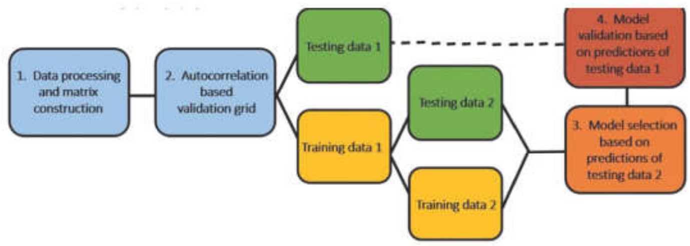


Fig 4: Methods

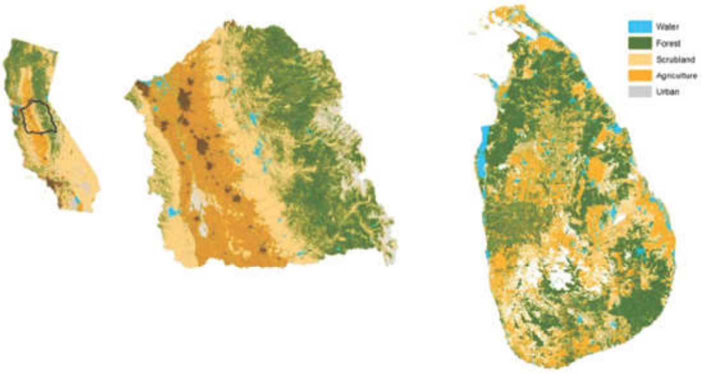


Fig 1: Land use in San Joaquin Valley, CA and Sri Lanka

Gradient-boosted machines model learns model learns potentially non-linear, complex relationships between past remotely sensed variable values and future remotely sensed vegetation health. We use a data splitting procedure to tune hyper-parameters and test the model to increase the probability of high generalizability to new data.

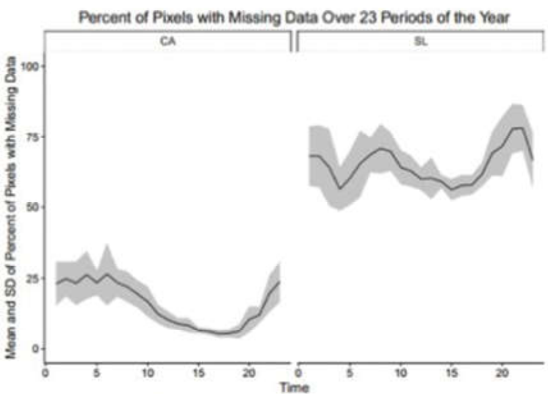
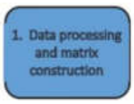
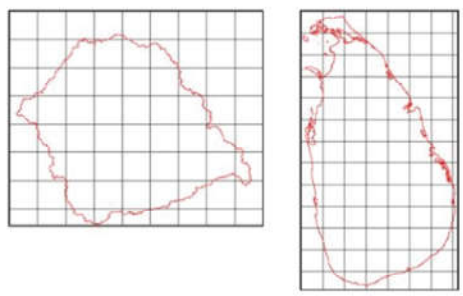


Fig 2: Data Availability



1. Download HDF data from NASA server
2. Mosaic, clip, and reproject datasets
3. Apply MODIS quality mask
4. Stack images into single matrix
5. Append time and location data

1. Calculate spatial autocorrelation to determine cell size
2. Create grid and select random subset as training data. The remainder of cells are flagged as testing data.



1 EVI lag

2 EVI lag, Land use, Time period

3 EVI lag, Land use, Time period, Level-3 products

4 EVI lag, Land use, Time period, Spectral data

	MODIS product	Layer	Description
Spectral Model	MOD09A1.005	B1_lag	Lag of MOD09 band 1, 620-670 nm
		B2_lag	Lag of MOD09 band 2, 841-876 nm
		B3_lag	Lag of MOD09 band 3, 459-479 nm
		B4_lag	Lag of MOD09 band 4, 545-565 nm
		B5_lag	Lag of MOD09 band 5, 1230-1250 nm
		B6_lag	Lag of MOD09 band 6, 1628-1652 nm
		B7_lag	Lag of MOD09 band 7, 2105-2155 nm
Level 3 Model	MOD11A2.005	LST_Day_1km_lag	Lag of daytime land surface temperature
		QC_Day_lag	Lag of quality control for daytime LST
	MOD13Q1.005	EVI_lag	Lag of enhanced vegetation index
		NDVI_lag	Lag of normalized difference vegetation index
		VI_Quality_lag	Lag of quality control for vegetation indices
	MOD15A2.005	Fpar_1km_lag	Lag of fraction of photosynthetically active radiation
		Lai_1km_lag	Lag of leaf area index
		Fpar_Lai_QC_lag	Lag of quality control for FPARand LAI
	MOD17A2.005	GPP_lag	Lag of gross primary productivity
		PSN_lag	Lag of net photosynthesis
Level 3 & Spectral	Ancillary data	Land_use	SL Survey Department, National Land Cover Database
		nino_lag	Lag of El Nino sea surface temperature index
		GWP_lag	Lag of population

Fig 3: Predictor variable sets

1. Learn models on Training Data 2, varying hyper-parameters for each estimation.
2. Predict Testing Data 2.
3. Repeat 1-2 with the four different data types.
4. Choose combination of data type and hyper-parameter setting that led to the highest performance in predicting Testing Data 2.
5. For validation on held-out data, use that selected best performing model to predict Testing Data 1.
6. Repeat 1-5 separately for Sri Lanka and California.

3. Model selection based on predictions of testing data 2

4. Model validation based on prediction of testing data 1

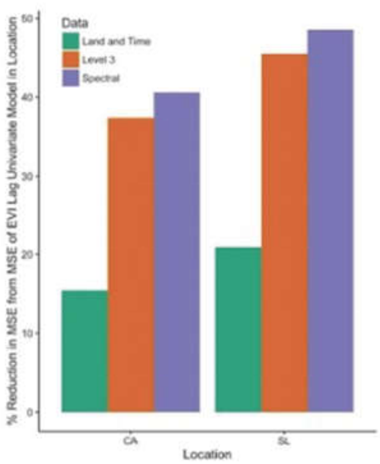


Fig 5: Performance relative to simple EVI lag model

In both locations magnitude of error reduction between predictor variable sets is similar. Error is reduced by 40% - 50% when moving from only EVI Lag to EVI Lag and Spectral data. Computed correlation between predicted and actual values of EVI in the held-out data through time (Fig 6), across land-use categories (Fig 7), and at different values of EVI (Fig 8). Period of low correlation follow periods of high cloud contamination (see Figure 2).

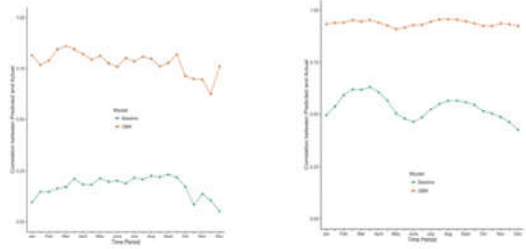


Fig 6: Performance across time

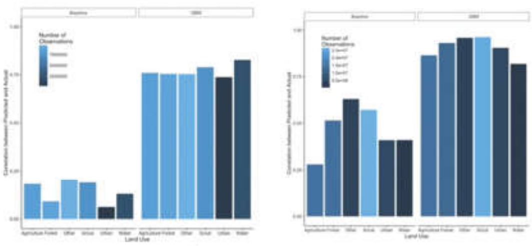


Fig 7: Performance across space

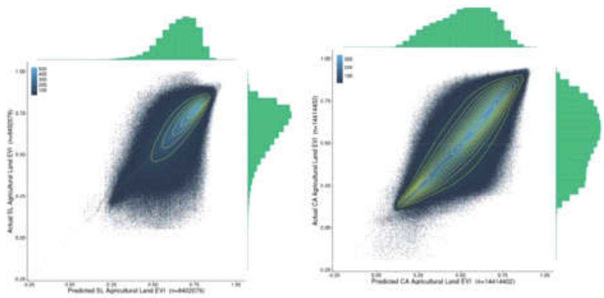


Fig 8: Performance across values of EVI

The way forward 2016-2017

Mr. W. G. Winson Gnanatheepan
(Climate Research Unit Coordinator), National Building Research Organisation

Following activities have been planned for the next 12 month period under ADAPT-SL Project.

1. Development of Community Profiles and Geo Spatial Mapping

Community profiles will be developed for 24 GNDs using primary data collected through questionnaire survey which is known as Sri Lanka Environmental and Agricultural Decision-Making Survey (SEADS-HH) conducted by enumerators from NIELSON, Sri Lanka. Collected primary data will be used to evaluate the socio-economic status of the target farmer groups. Further Complex Stakeholder Perception Mapping was done using the data collected through questionnaire survey.

Geo-spatial mapping will be carried out in 24 GNDs using satellite images and drone technology.

2. Thermal comfort and housing construction

Objective of this task is to develop guide document for ensuring thermal comfort designs in Dry zone, to reduce social drought conditions and to reduce the economic expenditure.

This assessment will be done based on materials, design, climate condition and landscape. A design guideline for suitable concept, material usage and landscape will be developed for dry zone house construction using this research outcome. It is estimated that 200 buildings will be analysed under this study.

3. Climate Resilience Application

Ultimate outcome of the ADAPT-SL is to enhance the climate resilience capacity of the target farming community. This initiative also expects to implement and monitor the community system variations in the dry zone irrigation system.

Hence, 12 small scale community based projects will be implemented in selected 12 GNDs and 2 medium scale projects will be implemented at Huruluwewa (System M/H) and Ibbanwela Wewa (System B). The concept of community architecture will be adopted to design and implement these projects.

CAP workshops and Focused Group Discussions will be conducted to identify the real community problems and expected solutions from the community. Further technical sessions conducted with identified stakeholders to prepare design and formulate implementation mechanism for the identified strategies as a solution for community grievances.

This Newsletter is published under the collaboration project between Vanderbilt Institute of Energy and Environment (VIEE), USA and National Building Research Organisation (NBRO), Sri Lanka on Technical Co-operation to carryout research project on Agricultural Decision Making and Adaptation to Precipitation Trends in Sri Lanka.

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