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SENSING PROGRESS: SPACE SOLUTIONS FOR FOOD & WATER SECURITY

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Abstract

With food and water security presenting one of the 21st century's key challenges, this paper undertakes an examination of potential space solutions that could assist in tackling this pressing issue. With a focus on application within the Global South, Sensing Progress is the result of a 5-week project involving 31 participants from 11 countries who together identified three core issues contributing to contemporary food and water insecurity. These comprise urbanization and population growth, climate change and also the extreme weather events of flooding and drought. The current work of international programs and organizations engaged in this field, such as the Group on Earth Observations' Global Agricultural Monitoring (GEOGLAM) program, is further explored with a view to promoting such international endeavors. Separately the novel concept of an Orbital Seed Vault is also discussed as a means of preserving humanity's long-term access to food in the face of cataclysmic disaster. Ultimately three main recommendations are proposed for consideration by the international community. The first, international data sharing, involves the open and timely sharing of Earth observation data, experience and information resources among nations and people. The second recommends expansion of current Earth observation programs, for example the Remote-sensing Information and Insurance for Crops in Emerging economies (RIICE) program. Such expansion should include strengthening of existing State engagement with such programs and the extension to further States not yet involved. The third recommendation surrounds capacity building, with the call for national governments of the Global South to fund Earth observation and remote sensing education and outreach programs. These capacity building initiatives should be supported by well-developed communications infrastructure and access to relevant hardware and software platforms. Also proposed and discussed in detail as a distinct new capacity building measure is the creation of a Center for Food and Water Security Management in the Global South. This paper arising from the 2016 Southern Hemisphere Space Studies Program held in Adelaide, Australia, brings to this issue the unique international, intercultural and interdisciplinary perspective that such programs of the International Space University are renowned.

Keywords: ***Food Security; Water Security; Global South***

1. Introduction

During January and February 2016 31 participants from 11 nations convened in Adelaide, Australia, for the International Space University's (ISU) 2016 Southern Hemisphere Space Studies Program (SHSSP). Hosted by the University of South Australia, participants were tasked with researching and drafting a White Paper that examined current and emerging space-based (and accompanying terrestrial) solutions to food and water security in the Global South.

Defining this region of the world as countries intersected or falling below the Tropic of Cancer, this represents the four main regions of the Southern Hemisphere (Africa, Asia, Oceania and Central and South America) and constitutes approximately two-thirds of the Earth's population. These four regions exhibit great difference in their levels of economic development, climatic and environmental conditions, politics, language and culture. Yet the common challenges to food and water security of population growth, climate change and extreme weather events are shared dangers in the threat they pose across the Global South.

Adopting a mission statement of "to propose internationally cooperative methods to countries of the Global South for developing and strengthening food and water security strategies using a combination of space-based and terrestrial resources", the diverse group comprising the 2016 SHSSP adopted the ISU's "3 I's" approach in delivering their White Paper. For in producing their 50 page report entitled "Sensing

Progress: Space Solutions for Food & Water Security" [1], all 31 participants drew upon the "International, Intercultural and Interdisciplinary" framework for which ISU is renowned in both the aerospace and higher education sectors.

This paper synthesizes and condenses this White Paper emanating from the 2016 SHSSP, reporting on the findings and recommendations it delivered that engage space technology and resources in improving food and water security in the Global South as we progress further into the 21st century.

Fig. 1. SHSSP 2016 team logo
(Source: Lydia Drabsch)

As defined by the World Health Organization, "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"[2]. Unfortunately however, one in eight people on our planet fail to meet this benchmark, suffering from undernourishment [3]. The related issue of water security involves the capacity of human communities to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, well-being and socio-economic development [4].

Although there are a multitude of important issues affecting food and water security in the Global South, a broad area of the world containing most of the world's developing countries, SHSSP participants elected to focus on three key issues. These comprised *Urbanization and Population Growth*, *Climate Change* and *Extreme Weather Events (Flooding and Draught)*. Each of these issues was chosen given their significant respective impacts on the abilities of particularly developing countries within the Global South to provide food and water security for their populations.

2. Urbanization and Population Growth

The proportion of the Earth's population located in cities currently stands at 54%, with this expected to rise to 66% by 2050 [5]. As urbanization increases and the geographic area covered by cities expands, there is increased demand on existing water sources. This interrupts the natural water cycle of urbanized regions, decreasing their water security [6]. Increasing urbanization also decreases the availability of fertile arable land [7].

Growth and urbanization also generate significant pollution outputs, such as black carbon, nitrogen oxides, ozone and sulphur dioxide. These pollutants exert a range of harmful effects of food crops, including starving plants of sunlight and exposing them to excessive toxicity. Studies also reveal that crops exposed to such air pollution also exhibit far lower yields. [8, 9]

Space technology has an important role in assisting to minimize the detrimental effects of urbanization and population growth. As space-based solutions can provide a unique perspective informing urban planning and management activities. Remote sensing systems can monitor the effects that urbanization has on water quality and availability. It has been proposed for example that remote sensing could be used to detect suspended particulate matter (a prominent source of pollution) in bodies of water [10]. By also combining such remote sensing systems in space with terrestrial sensor networks, the ability to detect air and water pollution events in near-real time becomes possible. Such monitoring enables governments to mitigate the damaging effects of such pollution events as they occur.

Furthermore Earth observation systems can also play an important role in validating hydrological models that are used as part of 21st century urban planning. By utilizing such space-based observation technology, the number of impermeable surfaces can be reduced and the effects of urbanization on the water cycle can be minimized [11].

3. Climate Change

The last century and a half have witnessed a steady increase in the average global temperature, of just under 2ºC. [12] This temperature increase has resulted in widespread environmental consequences including rising sea levels, storms, floods and draughts. All of these environmental effects, collectively known as climate change, represent significant challenges to agriculture and its associated water requirements.

Climate change has been defined by the United Nations in its Framework Convention on Climate Change (UNFCC) as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time periods” [13].

The Intergovernmental Panel on Climate Change (IPCC) Synthesis Report 2014 details a range of current climatic changes and subsequent impacts occurring at the global level. It notes changing precipitation and melting snow and ice are negatively affecting water resources in many regions, from which the Global South is not immune. The geographic ranges, migration patterns and abundance of several marine species (including some which represent a food source for humans) have also shifted in response to climate change. This rise in temperature across the planet has damaging effects on global crop yields, which are not offset by new arable land emerging in some limited areas (eg. Greenland) as a result of global warming [12].

Space-based technologies, particularly Earth observation satellites, enable the effective remote monitoring of the effects of climate change on the environment. This data is analysed by scientists and then disseminated to improve farming practices and inform policymakers.

The Group on Earth Observations (GEO) is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS). Established in 2005, GEOSS comprises a voluntary partnership of some 80 governments and 52 international organizations that links Earth observation, information and processing systems to improve the monitoring of the state of the Earth and its environment.

GEO’s Vision For Combining Space-Based Earth Observations With International Cooperation and Collaboration

“GEO is a strong advocate for sustained and coordinated climate observing systems. It is supporting an ambitious and multidisciplinary effort to strengthen the ability of governments to minimize and adapt to the societal and environmental impacts of climate variability and change. As it matures, GEOSS will represent a quantum leap in the speed, resolution, accuracy and sophistication of weather and climate modelling and forecasting. No single country or group of countries has the resources to achieve these advances on its own, but international collaboration promises to advance climate research and monitoring by ensuring that national investments are coordinated and mutually supportive. To strengthen the link between the providers and users of climate data and predictions, GEOSS disseminates user-friendly information and decision-support tools. Meanwhile, GEO plans to build capacity for using climate and Earth observation data and products more effectively and to integrate climate risk management into national policies for sustainable development” [14].

In September 2015, GEO also helped launch the Global Partnership for Sustainable Development Data (GPSDD) to support the United Nations’ Sustainable Development Goals. Among these 17 goals world leaders adopted as part of the 2030 Agenda for Sustainable Development is tackling climate change. GEO being identified as “one of a number of anchor partners and champions supporting and shaping the GPSDD’s vision for a better world through data sharing.” [15]

One of the participating organizations within GEO of particular pertinence to the issue of climate change is the Global Climate Observing System (GCOS). Its mission is “to enable the availability and quality of the atmospheric, oceanic, terrestrial and related Earth observations needed for monitoring, understanding, predicting and protecting the global climate system and providing communities and nations with assistance to live successfully with natural climate variability and human induced climate change” [16]. Furthermore the GCOS Cooperative Mechanism was established to identify and make effective use of available resources for improving climate observing systems in developing countries, particularly to enable collection, exchange and utilization of data in pursuance of the UNFCC [17].

4. Extreme Weather Events: Flooding and Draught

Food and water security are difficult to maintain when confronting severe weather event such as floods, draughts and other natural disasters.

A flood is generally defined as an overflow of water onto normally dry land. A flash flood can be caused by heavy or excessive rainfall or a dam failing, usually being characterized by raging torrents of water that rip through river beds, urban streets or mountain canyons [18]. Flooding accounted for 47% of all weather related disasters in the past 20 years, negatively affecting a total of some 2.3 billion people [19].

Many countries of the Global South are particularly vulnerable to flooding. For example twelve of the top fifteen countries with the greatest number of people exposed to river flooding risk fall within the Global South, highlighting the importance of flood mitigation in this region [20].

Drought results from lower than expected precipitation and high demand on available water supplies. Droughts have a severe impact on agricultural production and water supply, as decreasing crop yields impact food prices, global markets and consumer demand. More than one billion people globally were affected by draught in the previous 20 years, comprising more than a quarter of all people affected by all types of weather-related disasters worldwide in this period [19].

Drought intensity and frequency is unevenly distributed across the planet. The main regions of impact are temperate zones, many of which fall within the Global South. Approximately 80% of the world's agricultural land is rain-dependent, resulting in mitigation strategies including those informed by space-based technologies proving essential in building ecological resilience in drought-prone and semi-arid agricultural areas.

Space-oriented solutions helping to address flood and drought focus upon remote sensing satellites that are used to monitor water levels, inundation, soil moisture and general crop health. Hydrological models interfaced with Geographic Information Systems (GIS) data enable monitoring of water levels in flood prone areas and the creation of three dimensional maps evaluating potential drainage issues across terrain. Using such GIS modelling techniques in conjunction with rainfall data can be used to provide real-time understanding of water distribution [21].

The levels of moisture contained in soil can also be detected by satellites and used to ascertain drainage efficiency in flooding situations and likewise help to predict crop yields in drought conditions [22]. Such remote sensing techniques can provide accurate measurements for the top few centimeters of soil, where soil moisture can vary rapidly in response to rainfall and evaporation. The implementation of such moisture measurement techniques using satellites in Brazil enabled a 4.3% accuracy improvement compared to ground based measurements. [23]

An organization that facilitates space-based multi-spectral remote sensing technology is the GEOGLAM Agricultural Monitoring Portal. An initiative launched by the agriculture ministers of the G20 economies in 2011, GEOGLAM aims to strengthen global agricultural monitoring by improving the use of remote sensing tools and helps reinforce the international community's capacity to produce and disseminate agricultural forecasts from national to global scales. It does this by utilizing existing space-based monitoring programs and aims to strengthen them through networking, operationally focused research and data sharing [24]. The GEOGLAM Global Agricultural Monitoring portal is a demonstration of this, being employed to provide a near global measurement area for prediction of crop yield. This being particularly valuable in areas where ground based measurements are impractical or costly to implement, allowing for greater determination of areas at risk to extreme weather events such as flood and draught.

For the most effective use of remote sensing data in addressing flood and draught weather events, systems are needed to manage this data and deliver appropriate policy responses. One such existing system is the Remote Sensing-based Information and Insurance for Crops in Emerging Economies (RIICE) which is a collaborative program that collates remote sensing data on rice production to provide assessments of crop yield and losses from natural disasters [25]. The information is shared with insurance companies so that fairer insurance policy coverage can be provided to rice farmers. The RIICE project is currently active in the Southeast Asian countries of Vietnam, the Philippines, Cambodia, India, Indonesia, Bangladesh and Thailand until at least April 2018.

Remote Sensing-based Information and Insurance for Crops in Emerging Economies (RIICE)

The RIICE program provides imagery from remote sensing satellites to governments as part of a public-private partnership to monitor the size and growth of rice crops. This foodstuff account for 31% of caloric intake in Southeast Asia [26]. RIICE uses data acquired using Synthetic Aperture Radar, which can peer through the cloud cover which is prevalent during 70% of the rice production season. RIICE enhances data accessibility for participating Southeast Asian countries by utilizing low-cost cloud computing and automatic processing of datasets. The program was able to provide critical food map information after extreme weather events in Thailand and the Philippines within a matter of days. In addition, RIICE has implemented training programs for over 300 employees of agricultural management agencies across Southeast Asia to help expedite the use of this remote-sensing information in planning and policy decisions [25].

5. SHSSP 2016 Stratospheric Balloon Team Project

Fig. 2. The stratospheric balloon and payload just prior to launch
(Source: Dr Rowena Christiansen)

Satellite imagery of the Earth's surface is freely available to anyone with an internet connection, however there remain large swathes of the planet that do not enjoy internet coverage. Many of these internet blackspots fall within the Global South. People located within these areas, particularly agricultural and livestock farmers, could benefit greatly from access to information derived from satellite imagery.

One possible solution available to communities and food producers without access to satellite imagery via internet connectivity is to perform their own localized, small scale remote sensing. A low-cost means of undertaking such remote sensing operations is through the basic technology of stratospheric balloons. While motorized aerial drones are easier to control and recover for remote sensing purposes, they can be prohibitively expensive and are difficult to repair if damaged. Stratospheric balloons present a far cheaper, more robust alternative to implementing remote sensing technology.

To demonstrate the capability of a stratospheric balloon to remote image vegetation at low cost and in the absence of extensive infrastructure, participants of SHSSP 2016 employed a relatively simple "cubesat" payload carrying three cameras designed to capture visible and near-infrared images. This payload took less than a week to assemble by a small team of six participants. It was successfully launched on 26 January 2016 from the Mount Barker High School in the Adelaide Hills region on a helium filled stratospheric balloon. This launch was facilitated by the Amateur Radio Experimenters Group (AREG) of South Australia, with Adelaide company Launchbox providing the power supply and camera modules for the payload.

The area around the Mount Barker township, including viticulture crops in the wine producing Adelaide Hills region, were successfully photographed with the payload cameras capturing imagery in the visible and near-infrared range up to 37km above the surface. This entire project was also completed for less than AUD$2500 (USD$1,900), aptly demonstrating the high quality and locally relevant remote sensing imagery that can be independently achieved for a comparatively low price.

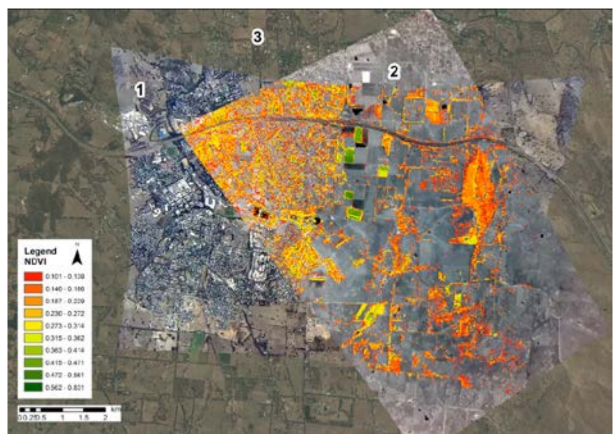

Fig. 3. Mid-altitude processed image from the stratospheric balloon launch of the Mount Barker area
(Source: Gustavo Fonseca Naranjo, Melissa Mirino, Rashmi Nayar and Jackie Slaverio)

6. Orbital Seed Vault Concept

Food security encompasses the management, expansion and preservation of adequate access to food across the short, medium and long-term. One means of protecting and preserving our species' access to agricultural foodstuffs over the long-term is through the operation of seed banks. A seed bank (also known as a seed vault) is a form of biorepository designed to preserve plant seeds as genetic material. These secure storage facilities hold seeds for long-duration periods in conditions designed to ensure their preservation.

Of the world's approximate 1700 seed banks, the Svalbard Global Seed Vault currently provides humanity's highest level of protection for seeds, including our planet's staple food crops. Located on the Norwegian archipelago of Svalbard, high above the Arctic Circle, this seed vault embedded 120 meters within a sandstone mountain holds a total of some 860,000 seeds in trust for virtually every national government on Earth.

While the Svalbard Global Seed Vault provides the best protection here on Earth for our most important agricultural specimens, it does not however present the most secure location available. Given the susceptibility of our planet to catastrophic events such as asteroid impacts, global pandemics and nuclear war, the environment that affords the highest level of protection for seeds of Earth's staple food crops is actually outer space. While a seed vault located on another celestial body would provide the strongest guarantor of the continuance of this crucial agricultural biodiversity, the outer space location currently most suited is in high Earth orbit high. Such an "Orbital Seed Vault" could store a small collection of seeds from the world's key food crops within a specially designed satellite.

Safely preserving these seeds in an orbital location would require countering the effects of space radiation, in the form of both high energy Galactic Cosmic Rays and lower energy Solar Energetic Particles, to ensure the genetic integrity of seed samples stored. A potential countermeasure against this may become available with the European Union funded Space Radiation Superconducting Shield project which is developing a shielding system based on superconducting magnets to deflect both high and low energy space radiation [27]. Just as this technology could potentially in the future shield astronauts on long-duration space missions, it could likewise potentially protect seed samples contained within an Orbital Seed Vault.

As a proof of concept, participants in the 2016 SHSSP included inside their stratospheric balloon payload a collection of seeds in order to replicate the parachute landing phase of this proposed Orbital Seed Vault concept. This experiment was entirely successful, with all seeds carried (corn, pumpkin, tomato and carrot) landing intact and fully retrieved. Although unable to be replicated in this stratospheric experiment, previously seeds have successfully been launched within satellite payloads, orbited Earth and then deorbited. In 2006 a Chinese satellite carrying 215kg of seeds circled the Earth and deorbited after 15 days [28]. Some 14.5 million tomato seeds also formed part of the Long Duration Exposure Facility experiment successfully conducted by NASA in low earth orbit from 1985 to 1900, with few plant mutations observed after these seeds were subsequently successfully planted [29]. Seeds stored in proper refrigerated conditions can in fact last almost indefinitely, with wheat, corn and rice seeds all able to be preserved in such conditions for over 1000 years [30].

7. Recommendations

As a result of the detailed consideration of the three analysed issues of *Urbanization and Population Growth*, *Climate Change* and *Extreme Weather Events (Flooding and Draught)* participants in SHSSP 2016 developed three overarching recommendations for space-based strategies to address the food and water security challenges faced by the Global South in the 21st century.

> ***Recommendation 1: International Data Sharing***
> The open and timely sharing of Earth observation data, experience and other information resources among nations and people is recommended. This tangible exchange will foster broader bilateral and multilateral cooperation, enhancing food and water security.

International collaboration should focus on the actual exchange of space-derived data and sharing of analysis systems and techniques. Adequately feeding and hydrating all the people of our planet requires sharing our collective capabilities and tools. This necessitates the sharing of data, experience and other information resources. Much of this relevant information is obtained from space-based assets such as Earth observation satellites, with improved information sharing between governments enabling the effective advising of farmers on the ground.

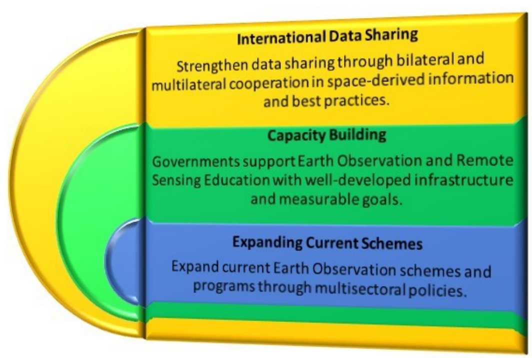

Fig. 4. The three interlinked recommendations arising from the 2016 SHSSP (Source: Dr Rowena Christiansen)

Further opportunities for increased international cooperation and engagement in the realm of space-based agricultural, hydrological and weather data exist across the full range of space operations. Cooperation can for example be as simple as the distribution at low or no cost of the specialist software needed to properly process and assess remote sensing data. Engagement of the private sector, comprising both traditional space industries and NewSpace actors, should also be fostered and encouraged.

Recommendation 2: Expand Current Schemes

Expand current Earth observation programs by establishing multisectoral policies and programs focused on strengthening food and water security within States where such schemes are already prevalent, and to States where such schemes would greatly improve the quality of life. In particular, successful programs such as RIICE should be expanded to cover a greater number of countries.

Food and water insecurity are complex and multifaceted issues that are interlinked to a great extent and caused by a variety of factors. It is proposed that by establishing multisectoral policies and program, current Earth observation schemes can be expanded to address the issues of food and water security in a holistic manner.

Programs such as RIICE effectively use Earth observation data to communicate with farmers to improve crop yields as well as assist governments in providing accurate assessments of the financial value of particular crops. RIICE has been successfully implemented in eight countries in Southeast Asia, with it being recommended that the geographic scope of this program be extended further to maximize benefits to agricultural producers in a larger region of the Global South.

Recommendation 3: Capacity Building

Governments in the Global South should invest in capacity building by funding Earth observation and remote sensing education and outreach programs. These programs should be supported by well-developed communications infrastructure and access to relevant hardware and software platforms. These programs should be accompanied by setting measurable goals to assess performance.

Earth observation data is freely available via the internet, yet some of the people who would benefit most from this data are unable to access and interpret it in a meaningful way. We recommend that governments in the Global South expand current agricultural education programs to include training on the use and benefits of remote sensing systems and how to convert raw data derived from space-based technologies into useful information on the ground. In countries where no such existing agricultural programs exist, we call for governments to initiate these programs.

Education by itself however is not enough. Governments should create communications infrastructure to ensure individuals, particularly farmers, have access to Earth observation data. Furthermore, governments should also facilitate access to computers and image processing software so that the Earth observation data can be converted to relevant agricultural information.

It is also crucial that some program performance measures be considered. This provides feedback showing that agricultural practices are being improved and whether the capacity building program is having the desired impact on a region. Possible performance indicators include mean income values and crop yields.

8. Center for Food and Water Security Management in the Global South

In line with this third recommendation of Capacity Building, a specific concept for a small center for food and water safety was developed by SHSSP participants. This proposed center will gather and share already available space data, and provide early-warning information to prepare for flood and drought seasons. It will also provide on-site and distance education and training on growing crop techniques. The center aims to research and develop inexpensive and user-friendly space-based applications and solutions to aid farmers and water resource managers. Further, it would work to influence policy-makers on the management and preservation of food and water security. As envisioned, the center would link with well-established research and educational programs such as the UN-affiliated 'Regional Center for Space Science and Technology Education for Latin America and the Caribbean' (CRECTEALC) and expand on already operational centers, like, RIICE and the 'Famine Early Warning Systems Network' (FEWS Net). The modest funding needed to establish this small centre could be supplied by governmental or non-governmental research organisations, mainly from countries of the Global South.

Objectives

- Coordination and integration of international space-related resources, and make Earth monitoring information (relating to food and water safety) from space available to the general public;
- Comprehensive assessment of food security and water resources in the Global South through large data analysis techniques;
- Provision of early warning and prevention information to relevant countries and institutions, along with intervention where necessary, and
- Access to on-sight and distance learning and

training, promotion of new technology and products, provision of research and development facilities, information services and legal aid.

Operational Mode

- Daily operation of the center is envisaged through cooperation of the major non-governmental food and water safety organizations in the Global South;
- The center would be located primarily in the more developed countries of the Global South, like, Australia and South Africa, with the potential for countries like Brazil and India to set up sister-organizations in the future;
- The center would be equipped with the same information resources, data analysis and research facilities, early warning technology and educational, technical and legal supports.

The overall framework of the center is outlined below:

A. Data Acquisition and Sharing

For this proposed center, work does not just involve carrying out data collection but also coordination and integration of global data, especially for the Global South where space surveillance data is rare and very expensive.

The center will look into different ways and agreements to purchase space-based Earth observation information involving food and water security in the Global South in addition to meteorological satellite information. However, it is important that data obtained through cooperation with other organizations is up-to-date and synchronized with current satellite data as far as possible. In cases of emergency, there may be the need to increase density and accuracy of satellite observations.

For food and water security management, it is crucial to access and share two types of data: meteorological and remote sensing information. Access to these types of information requires a “center-to-center” approach. For instance the proposed center could be connected with China's meteorological center (National Satellite Meteorological Centre) for Fengyun-2/3 meteorological satellite cloud pictures every day in accordance with the applied protocol requirements. Likewise it could also potentially be connected with the Chinese “Gaofen-1” remote sensing satellite data application center (China Center For Resources Satellite Data and Applications) for access to remote sensing data of various regions of the Global South, again according to a specific protocol. This “center-to-center” approach could also be established with the United Nations, European Union, NASA, ESA, JAXA, CNSA, and other space agencies and non-profit organizations around the world for data acquisition and sharing.

B. Data Analysis Department

One of the main tasks of the center is to process and analyze the acquired space and ground data into food and water security assessment reports for the Global South. This assessment should be objective, accurate and in real time.

C. Early Warning Systems

Untimely information release of warning and prevention measures are major causes of food and water insecurity. The centre will ensure timely release of early warning, and constantly updated early warning information.

The centre will establish food and water safety information analysis models, and develop user-friendly software and mobile applications that will analyze the data obtained in a timely manner. If the results of the analysis indicate a need for an early warning, the center would be responsible for the early warning information service - including region, warning reasons and the degree of hazard - to the relevant departments of the United Nations, European Union and other associated states or regions. The center will, at the same time, continue to monitor any change in results and keep the relevant states and departments informed of the latest warning till the warning is lifted.

D. Research and Development Department

It is proposed the center should include a Research and Development Department to develop the latest technology and products involving food and water safety management. Below is a list of research that can be done at the center:

a. Laser-based Lidar Technology (Remote Sensing technique) in Agriculture [31]

Laser-guided land leveling techniques, derived from laser-based Lidar technology, have been used to prepare the ground for production in Australia. It was observed that such measurement strategies have contributed to a 60% improvement in water use efficiency.

<u>Limitations</u>

This technique is unfeasible because of the high cost of equipment and precision, and lack of government investment support [32].

Future Application

This technique still needs to be demonstrated and tested in developing countries. If a precise system is successful, this can result in greater productive use of water and food [32].

b. Irrigation Real-time Management Kinematics Technique (Satellite Data) [3]

In California, farmers can go online and access detailed data, helping them calculate the optimal amount of water to apply. In a pilot study, this kind of technique reduced their water use by 13% whilst increasing their yields by eight percent.

Limitations

This technique has been applied in only five percent of the irrigated cropland in California. Although the technique of real-time kinematics has good accuracy, it is difficult to set-up and manage effectively and needs further improvement.

Future Application

A coalition of farmers, companies, and organizations across the food supply chain could make real progress toward the use of this technique.

c. Seeds from Space Synthetic Biology Technology [34]

China has sent more than 400 plant seed species to space since 1987. The method has produced giant eggplants, half-meter long cucumbers, and peppers with improved yields and reduced seeds [35].

Limitations

The major constraints are vessel size and high cost. Larger vessels allow for more goods to be carried but also require larger crews to maintain them, thereby requiring more resources.

Future Application

1. Solve the food insecurity problem in extreme environments or states with extremely less resources;
2. Use of new biological technique to feed growing population;
3. Advanced technical points need to be settled
4. The hazards induced by radiation are hard to overcome; and
5. Autonomous enclosed ecosystem ensures a sustainable presence of humans in outer space [36].

d. **Undersea Farming Addressing Food after Flood** [37]

The technique of undersea farming has been used in Northwest Italy under the project “Nemo’s Garden.” There lies a cluster of balloon-like pods under water, and, inside each of them, a range of plants are being grown, including red cabbage, lettuce, beans, basil and strawberries.

Limitations

With the current technology, the pods can only be submerged from five to eight meters below the surface.

Future Application

To cultivate seeds on the soil after flood.

E. Education and Training Support Department

- On-sight education and professional training by experts in food and water management matters.
- Public and open-source education for all through remote technology.
- Three-dimensional education: Varied disciplines of education touching policy making, law, entrepreneurship, engineering solutions, amongst others.

F. Legal Support Department

- For personnel problems encountered in the food and water security issues.
- For guidance about policy making and enforcement of an organization.
- For furthering human rights as they relate to adequate access to food and water for all people.

The proposed Center for Food and Water Security Management will consider cheap and inexpensive ways to incorporate food and water security applications in the Global South. Further, it will expand on already existing centers by the usage and coordination of already available resources. For instance, it will work in line with other established centers such as CRECTEALC, RIICE and FEWSNet to:

(i) Gather, analyze, process and share open-access space data;
(ii) Train and educate farmers and the general public, not only about growing crop techniques but also on policy making and entrepreneurship;
(iii) Research and develop the simplest solutions, user-friendly applications for farmers and the general public;
(iv) Provide early warning systems of threats to food and water securtiy, and

(v) Promote new and emerging space-based technologies and products that can help address food and water insecurity in the world, especially in the Global South.

9. Conclusion

This paper, based upon the *Sensing Progress: Space Solutions for Food & Water Security* White Paper produced by the participants of the 2016 SHSSP, acknowledges the importance of informing decision-makers about the significant role that space-based technologies and information can play in tackling food and water insecurity in the Global South. With space-based assets at their disposal policy-makers at the international, national and local levels can develop and implement more effective policies designed to face the challenges of *Urbanization and Population Growth*, *Climate Change* and *Extreme Weather Events (Flooding and Draught)* that this paper focuses upon.

Ultimately however the respective nations of the Global South will alongside the three major recommendations canvassed in this report (and the proposal for a regional Center for Food and Water Security Management) also require individualized resource management plans to tackle their own unique challenges associated with ensuring adequate food and water for their respective populations. Ideally such national strategies should also include innovative and technological solutions, including the use of space-based applications in combination with terrestrial resources.

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