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Trends in earth observation

Volume 1

Earth observation advancements in a changing world

Edited by Chirici G. and Gianinetto M.

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Edited by

Gherardo Chirici and Marco Gianinetto

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Preface

Since 1986 the Italian Remote Sensing Society (Associazione Italiana di Telerilevamento – AIT) aims to disseminate remote sensing culture, disciplines and applications in Italy. Specifically, AIT's mission is to:

- Create a network of people from Research, Academia and hi-tech Companies interested in analysis, development and application of a wide range of remote sensing methods and techniques;
- Promote and coordinate initiatives to expand the use of remote sensing technologies in Italy and across the European Union;
- Foster the exchange of knowledge and cooperation between its members to "shorten" the chain: research→innovation→new applications/markets→research;
- Support the dissemination of remote sensing methods through the organization of congresses, conferences, working groups, including international thematic courses;
- Represent and take care of scientific and cultural interests in remote sensing for institutions, agencies, companies and similar associations, at national and international level.

Recently, AIT was included in the Italian Copernicus User Forum among the representatives of the IV sector. AIT is also the official Society of the European Journal of Remote Sensing, an open-access scholarly journal published by Taylor & Francis.
Until 1995, AIT was used to organise National Conferences, but in 1997, the Society joined a wider Federal Association (Associazioni Scientifiche per le Informazioni Territoriali e Ambientali - ASITA) related to Cartography, GIS, Topography, Photogrammetry and Remote Sensing, which organises annual national conferences to share and diffuse the Geomatic advancements.

In 2016 AIT decided to bring back its tradition to organize its national conferences with a more distinctive research trait. In addition, always in that year, AIT started to organize its annual International Summer Schools for the exploitation of Copernicus data and programmes.
In this framework, we decided to take the opportunity to create a new book series, officially supported by AIT, entitled *Trends in Earth observation*. These volumes want to present to the readers a snapshot of the state-of-the-art in several different application fields.
I hope that *Trends in Earth observation* can contribute to the scientific progress and the continuous innovation of Earth Observation.

AIT President
Livio Rossi

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Introduction

Earth observation advancements in a changing world

Chirici G., Gianinetto M.

Trends in Earth observation (ISSN 2612-7148) is a new series supported by the Italian Society of Remote Sensing (AIT) which purpose is to provide a new media for publishing the outcomes of high-quality researches. This series accompanies the well-established European Journal of Remote Sensing, which is the official journal of AIT, and shares its blind peer-review process. However, while the journal is general purpose, Trends in Earth observation addresses specific emerging topics organized into thematic chapters.

This first volume of Trends in Earth observation is entitled Earth observation advancements in a changing world and includes 47 contributions from colleagues belonging to 10 different countries, organized in 6 chapters. Compared to similar volumes which often focus on the techniques and methods, Trends in Earth observation also describes case histories. In this sense, it provides the present state-of-the-art of many real-world remote sensing applications.

The first chapter is specifically oriented to agriculture applications of remote sensing and authors present innovative applications for monitoring problems of different cultivations (coffee, rice, olive, maize, tomato, oil palm) in different environmental conditions and with different Earth Observation technologies.

The second chapter covers the very wide area of forest monitoring and environmental studies. Two of the most common issues are the recognition of tree species and/or forest types and the multi-temporal analysis of vegetation trends and disturbances.

The third chapter is focused on disaster risk and geomorphologic applications, also including some applications using UAVs which is a relatively recent new area of remote sensing applications.

The fourth chapter describes applications in the field of water management and protection, with a specific focus on the mapping of water resources with different data and different resolutions.

The fifth chapter addresses the monitoring of coasts and the last chapter reports new advancements in the monitoring of urban environments using either optical or radar images.

We gratefully acknowledge the contributions of all authors and hope you will enjoy reading this first volume of the new series Trends in Earth observation.

REMOTE SENSING CHARACTERIZATION OF CROP VULNERABILITY TO FLOOD

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KEY WORDS: MODIS Aqua; UNITAR UNOSAT; NDVI, SRTM; Water Footprint; Human Energy Requirements; Bangladesh; Pakistan

ABSTRACT:

The analysis of connections between natural disaster and food security is extremely relevant, especially in developing countries where food availability can be highly jeopardized by extreme events that damage agricultural areas and food stocks. In particular, flood events are the most impacting natural disasters on agriculture, with a percentage share of damage around 60%.
This work focuses on the food-flood nexus, developing a methodology for evaluating the effects of floods on food supply by integrating remote sensing data, agricultural statistics, and water footprint databases. Based on the existing literature about extreme floods, the Bangladesh flood in 2007 and the Pakistan flood of 2010 have been selected as exemplar case studies that can highlight the effects of flood events on food availability.
The analysis focused on rice as the most spread crop in Bangladesh, while it considers the national crop mix in Pakistan analysis.
Results showed that the use of remote sensing data combined with other sources of onsite information is particularly useful to assess the effects of flood events on food availability. The damages caused by floods on agricultural areas are estimated in terms of crop losses and then converted into lost calories and water footprint as complementary indicators.

1. INTRODUCTION

The inner connections among natural disaster and food security are extremely relevant especially in developing countries where the food availability (one of the four pillars food security together with access, utilization and stability, FAO 2009) can be highly jeopardized by extreme events that damage the primary access to food, i.e. agriculture.
The objective of this study is to analyze the impact of flood events on food security, taking advantage of remote sensing data to develop a methodology to rapidly determine crop losses due to submergence.
Based on the existing literature related to extreme floods, the events in Bangladesh (2007) and in Pakistan (2010) have been selected. Bangladesh and Pakistan have been chosen as exemplar case studies, because of their vulnerability to floods and the importance of agriculture in their territories. These case studies are characterized by significant differences in their agricultural production (mainly rice in Bangladesh and rice, sugarcane and wheat in Pakistan) allowing us to evaluate the effects of flooding on crops with different resistance to submergence.
The adopted method integrates remote sensing data, agricultural statistics, and water footprint values in order to (i) evaluating the potentially affected agricultural areas; (ii) converting the affected areas into crop loss; (iii) estimating the associated calories and embedded water losses.

2. METHODS AND DATA

Intersecting remote sensed flood maps with administrative and land use maps and then integrating the information regarding crops yields is possible to determine the potential crop losses.

Flood maps can be obtained by following one of the many existing classification algorithms on the basis of raw available satellite data or taking advantage of available remote sensing products, already classified for flood identification (Sanyal and Lu, 2004).
The conversion of potential crop losses into effective crop loss can be done taking into consideration the peculiarities of topography, land use and crops characteristics for the selected study areas. Additional information, such as specific crop resistance to submergence in terms of time and water depth might be added to refine the crop losses evaluation (Figure 1).

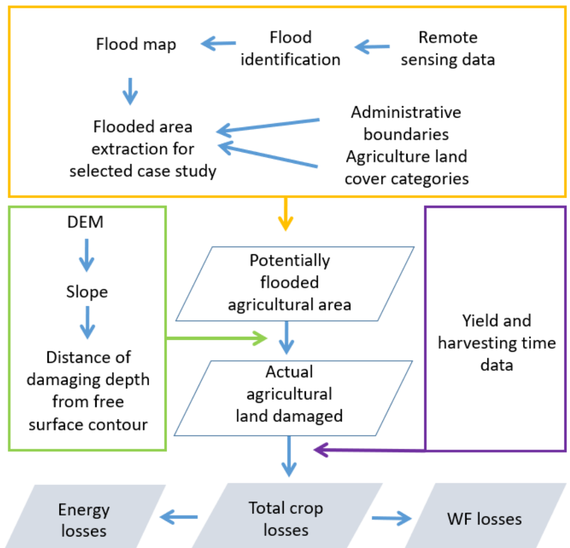

Figure 1. Methodology scheme

* Corresponding author

The final results are here expressed in terms of lost calories through the use of Human Energy Requirements indicator (HER, FAO 2001) or in terms of lost water through Water Footprint indicator (WF, Hoekstra et al. 2011) losses. Both these expressions are useful to convert the analysis into synthetic indicators: lost calories are a direct estimation of the crop losses while the WF allows an indirect evaluation of land use management criticalities both for supporting a complete diet and preserving local water resources.

2.1 Pakistan: multi crop losses

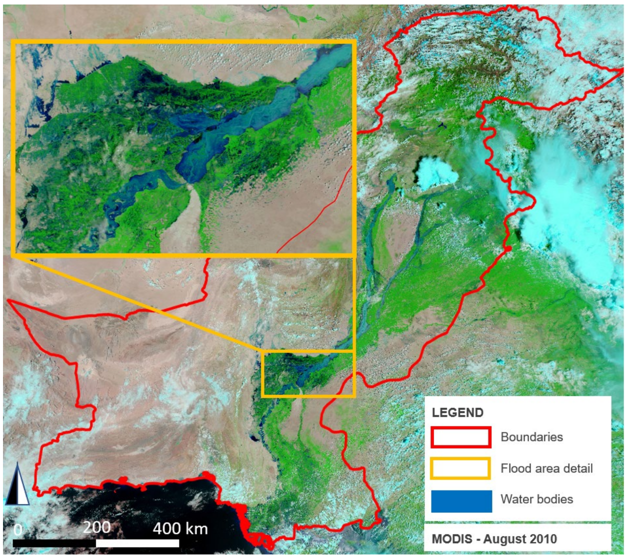

Figure 2. Flood areas identification (source MODIS, August 2010) Pakistan

For the Pakistan case study, the agricultural territories affected by flood are estimated making use of remote sensing derived data that are provided by Suparco and FAO, based on MODIS Aqua Satellite and SPOT VGT data (1 km spatial resolution, Suparco and FAO (2010)).
The flood involved an area with an extension of 58,797 km^2 with duration of around three months, from the end of July until the end of October (Figure 2).
All the main Pakistan crops have been considered together with wheat stocks. The characteristics of the crops in terms of yield are derived from FAOSTAT database (FAO, 2016). Using the FAOSTAT, the crops production data for the 10 years before the flood event, it is possible to calculate an average agricultural yield for the main crops lost (i.e. sugarcane and rice), as well as to estimate the actual crop losses (in term of weight). By knowing the energy content in kcal/ kg of the different crops, it is then possible to estimate the associated food energy losses, both in terms of vegetal and animal calories.

2.2 Bangladesh: focus on rice vulnerability

For Bangladesh case study, UNOSAT map of the flooded areas based on MODIS Aqua satellite data were used. It includes 30233 satellite detected water bodies with a spatial extent of 72,972 km^2 derived from the MODIS-Aqua image (250 m for band1–2500 m for band3–7 and 1000 m for band8–36) acquired on August 2007 and analyzed by a water detection algorithm for rapid flood mapping based on NDVI evaluation UNITAR UNOSAT (2007), Figure 3.
The land use data adopted are distributed by the Pacific Disaster Center, as institution reference of the Global Hazards Information Network (GHIN, 2008).

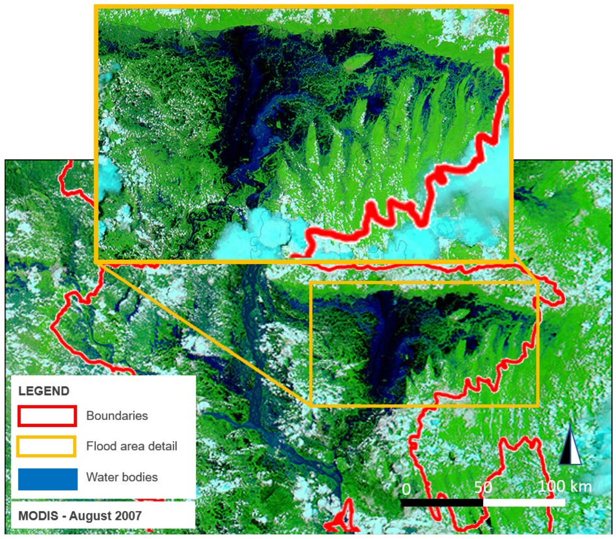

Figure 3. Flood areas identification (source MODIS, August 2007) Bangladesh

In the Bangladesh case study, the assumption that in the flooded area identified by the remote sensing all the crops are destroyed is not applicable because floods affect rice production proportionally to flood hydraulic height and length of the submergence period. Therefore, a threshold in time and space has been adopted to take into account the resistance of submergence of rice: 1-meter depth (according to deep water areas defined by Huke and Huke, 1997) and a period of submergence greater than three weeks (according to the International Rice Research Institute, 1976) have been assumed, as the limiting factors to rice growth.
The water depth in the flooded area was estimated integrating MODIS satellite images of 20 August with SRTM remote sensed topography data (van Zyl, 2001). In order to calculate the area included within the 0-1 meter depth, the slope of the DEM (SRTM) is calculated and used to estimate the average distance from the points where the water depth is 1 meter to the flood perimeter. The cultivated area not destroyed by the flood is therefore the product of the flood perimeter, times the average distance introduced before. The use of MODIS images from 20 August (six weeks after the beginning of the flood), guarantees that the time constraint is included.

3. RESULTS AND DISCUSSION

In the Bangladesh case study, the results depict an average loss of 103 kcal/capita due to flooded rice, representing 5.3% of the potential energy usually provided by this crop. If we consider the effects of flood only on the population of the affected districts, the result increases dramatically to 398 kcal lost (Table 1).

Rice type	Production losses for human use [103 ton]	per capita energy lost [kcal/cap/day] *	per capita energy lost [kcal/cap/day] **
Aus	76.1	5	20
Aman	1413.9	98	377
Total	1490	103	398

* evaluated considering the total population as affected
** considering only the population of the affected areas (i.e. 37, 908,436)

Table 1 Estimation of food energy losses in Bangladesh

The energy deficit due to the rice production lost, compared to the annual energy provided by the entire food production of Bangladesh in 2006, using the total kcal/cap/day supply of 2006 (i.e. 2417 kcal/cap/day) is 4.3% considering the total population as affected and it raises to 16.5%, if only the population of the affected areas is considered.

In order to properly understand the meaning of these percentages, it is important to highlight that the lack of food (and thus energy) caused by the flood is contributing to worsen the already critical situation of food supply in Bangladesh that was already suffering a 19.4% deficit.

Based on the existing statistics on WF in Bangladesh, lost food results have been converted in terms of water footprint to have another measurement of the flood effects on the territory. The results show a total WF of 4.72E+09 m^3 that is equal to 4.4% of the national WF (Table 2).

Rice type	Green WF [m3]	Blue WF [m3]	Grey WF [m3]	Total WF [m3]
AUS	1.79E+08	2.61E+07	3.61E+07	2.41E+08
AMAN	3.33E+09	4.85E+08	6.71E+08	4.48E+09
TOTAL	3.51E+09	5.12E+08	7.07E+08	4.72E+09

Table 2 Water Footprint of rice lost due to Bangladesh flood of 2007

In Pakistan, the results show a reduction of production that is about 19% for sugarcane and 40% for rice that is associated to a significant loss of energy available. The sum of crops and stocks destroyed amounts to a total of 205 kcal/cap/day lost, due the flood and it is equal to a loss of 8.5% of the Pakistan average food supply (10.7% if we consider only the energy derived from vegetal products).

As in the previous case study, the food losses results have been converted into WF resulting in total loss of 1.84 E+10 m^3 that is equal to 13.5% of the Nation WF.

The results highlight the countries vulnerability to flood, being both countries strongly dependent on local agricultural production. The 2007 flood event reflected badly upon Bangladeshi food security, almost doubling the existing food deficit. The same happened in Pakistan where an already scarce food supply has been worsened by the 2010 flood.

The results can be combined with other spatial analysis in order to provide a broader picture of the flood effects on a territory. An integration of flood extent with population poverty distribution is hereby proposed to identify the hotspots areas where flood strikes the poorest areas (Figure 4).

The strategies for disaster management and planning against flood risk should battle social disparities and focus on these areas that are often more vulnerable and less resilient to flood (Vojinovic and Abbott, 2012). This kind of analysis can provide useful information that help the definition of the priorities of intervention to support the poorest areas in case of flood events.

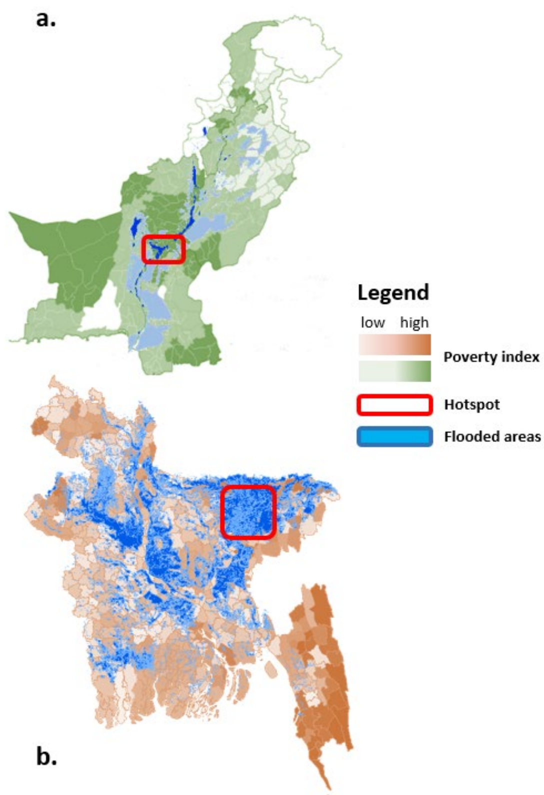

Figure 4. Identification of the poorest area affected by flood (a) Pakistan, (b) Bangladesh

4. CONCLUSION

The proposed framework, taking advantage of the integration of remote sensing data and agricultural statistics, provides a rapid assessment of flood effects on food security on the short term. Moreover, if combined with other spatial information, it can provide useful information that can be applied to spatially identify the hotspots and support long term planning.

Method results are fully repeatable; whereas, for remote sensed data the sources of data are valid worldwide and the data regarding land use and crops characteristics are strongly site specific, which need to be carefully evaluated.

This analysis focuses on direct flood damages to crops or food stocks. Food security could be strongly reduced by flood damages on pasture land, livestock, fisheries affecting directly or indirectly the animal calories and protein food intake (Davis et al, 2014). Additional side effects of flood events, such as the deposition of sediments on fields, the erosion of agricultural soil, the loss of soil nutrients as well as microbial and fungal activities are not explicitly considered here but could be an obstacle for future cropping possibilities and should be taken in account, too (Pimentel et al., 1995; Zhang et al., 2017). Other factors influencing future production may be the spread of insects that could be dangerous to cultivation due to the presence of stagnant water (Rosenzweig et al., 2001).

The combination with other spatial analysis provides a broader picture of the flood effects on a territory. In fact, the integration of flood extent with population poverty distribution here proposed, allow to identify the hotspots areas where flood strikes the poorest areas. This kind of analysis can provide useful information that help the definition of the priorities of intervention to support most vulnerable areas in case of flood events.

Flood risk has many hidden connections with environmental, social and economic spheres that need to be analyzed to develop effective integrated water-land management strategies. Our study makes a little step in this direction showing how remote sensing data can be mixed with on-site information to assess the effects of the flood on agriculture and how this information can be useful to enhance the resilience of local food production systems.

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