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A STRATEGIC PROGRAMME 5 – RESILIENCE INITIATIVE

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Notes on an information system on damage and losses from disasters in agriculture, fisheries and forestry

A Strategic Programme 5 – Resilience initiative

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Notes on an information system on damage and losses from disasters on crops, livestock, fisheries and forestry

A Strategic Programme 5 – Resilience initiative

1) *Justification and starting points*

Between 1980 and 2014, natural hazard-induced disasters caused USD 2.6 trillion in damages worldwide, affecting 6.4 billion people[1]. Furthermore, the frequency of weather and climate related disasters has increased significantly since the 1980s[2]. Such figures and trends are particularly worrying for the agriculture sector, which is highly dependent on weather and climatic patterns, and greatly suffers from the consequences of disasters.

In spite of the high impact of disasters on agriculture (including crops, livestock, forestry and fisheries), this effect is cannot be measured and monitored at national, regional or global levels because it is not systematically recorded or reported by governments, nor collected within existing global databases on disaster losses. Global statistics on the economic impact of disasters are collected and reported as a total sum for all sectors, and often do not accurately capture the impact on individual sectors. More specifically, the impact on agriculture is not always recorded and often remains unreported at national, and also global, level[3]. As a result, there is no clear understanding of the extent to which natural hazards and disasters impact the agriculture sector and sub-sectors in developing countries. Yet, sector-specific quantitative data on disaster losses are necessary to understand the breadth and scope of disaster impact on agriculture and livelihoods so as to design adequate responses. Better information on damage and losses from disasters can also be used to assess the benefits of increased investment in prevention, adaptation to and mitigation of risks.

In order to fill the knowledge and data gaps on disasters impact on agriculture, FAO will launch an initiative for the development of an information system on damage and losses caused by disasters on the sector and its subsectors (crops, livestock, fisheries and forestry). As part of its commitment to enhancing the resilience of agriculture and rural livelihoods, FAO will support member countries to collect and report relevant data on the immediate physical damage caused

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[1] Data from the International Disaster Database – Centre for Research on the Epidemiology of Disasters (EM-DAT CRED). Total damage is likely to be an underestimate, as only 36 percent of disasters reported in EM-DAT CRED include an estimation of damage.

[2] Based on data from EM-DAT CRED, the average annual number of climate-related disasters more than doubled in the decade 2003-2013 with respect to the 1980s.

[3] The Damage and Loss Assessment (DaLA) methodology (GFDRR, 2010) and the Post Disaster Needs Assessment (PDNA) Guide (EC, World Bank and United Nations, 2013) proposed the assessment of impact in different economic sectors, including agriculture. However, detailed information on the sector is in fact seldom available.

by disasters on agricultural assets, as well as on the cascading negative effects of disasters on agricultural production, and value chains.

Starting points of this initiative are the FAO study on "The impact of natural hazards and disasters on agriculture, food security and nutrition" (FAO, 2015) and the Rapid Agricultural Disaster Assessment Routine - RADAR (FAO, 2008).

In particular, FAO (2015) study presents the following analyses and findings:

- Trends on damage and losses caused by medium to large–scale disasters on crops, livestock, fisheries and forestry from 78 disasters occurred in 48 developing countries in Africa, Asia and Latin America over the past decade (2003-2013), based on information obtained from post-disaster needs assessments (PDNAs). According to this analysis, agriculture absorbed 22 percent of total damage and losses caused by natural hazard-induced disasters between 2003 and 2013, a figure much higher than previously reported[4].
- Crop and livestock production reductions associated with medium-to-large scale disasters that took place between 2003 and 2013 in 67 developing countries in Sub-Saharan Africa, Asia, Latin America and Caribbean (LAC), and the Near East. These are calculated for a selected number of agricultural commodities, as decreases in yields and production quantities after the occurrence of natural hazards, compared to linear trend values. According to this analysis, crop and livestock production losses averaged more than USD 7 billion per year between 2003 and 2013.
- Changes in trade flows associated with 116 disasters affecting 59 countries. Increases in imports are calculated as increases in the monetary value of imports in the year of disaster and following year, compared to the linear trend; decreases in exports are calculated as decreases in the monetary value of exports in the year of disaster and following year, compared to the linear trend. The analysis revealed that significant changes in agricultural trade flows occurred after medium- and large-scale disasters in developing countries. In particular, a positive correlation was found between disasters and increases in agricultural imports, as well as decreases in agricultural exports.
- A presentation of how disasters impact agricultural value chains, manufacturing and industrial output, trade flows, the balance of payment, the sectoral GDP growth, national GDP.
- An in-depth analysis of drought in Sub-Saharan Africa, based on trends since 1980 in the geo-spatial and temporal distribution of droughts across the sub-regions; this part includes details on crop and livestock production reductions associated with drought, as well as changes in trade flows, agriculture GDP growth and national GDP, as well as food security and nutrition. The study found that sub-Saharan African countries suffered significant crop and livestock production losses after droughts, with the highest losses experienced in eastern Africa.

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[4] In the 2013 Global Assessment Report, the monetary value of disaster impact was calculated based on physical impact indicators reported into 45 national disaster loss databases. Physical impact indicators included: houses damaged and destroyed; hospitals damaged; education centers damaged; damages in roads; crop hectares damaged; and livestock units lost. According to the estimated figures, agriculture (crops and livestock) absorbed about 13 percent of the total monetary value of disaster impact. See: UNISDR. 2013. *Global Assessment Report on Disaster Risk Reduction*.

The study was largely based on available secondary data. In the longer term, the FAO initiative aims at taking a broader perspective, to include primary data and improve the amount and quality of the information available and the methodology. For this purpose, a key methodological starting point is RADAR, a framework developed by FAO for data collection and analysis of disaster impact on agriculture (FAO, 2008).

The RADAR is an operational framework proposed by the Environment, Climate Change and Bioenergy Division (NRC) to analyze the interaction of the components of agricultural outputs with an extreme physical event. RADAR integrates physical models, knowledge-bases, databases and GIS technology in order to assess the short- and long-term impact of disasters on agriculture. RADAR is a first attempt of combining empirical and model analysis in order to analyze the interactions between a given natural hazard and the agricultural environment in a defined geographical area. The historical data on disasters impact should feed the calibration of a set of “transfer functions” that link the magnitude of the hazard with its intensity, and the intensity with the monetary impact on agriculture. RADAR was successfully tested to assess the impact of Hurricane Mitch on the Honduran agricultural production system, and more recently resumed and applied to Typhoon Haiyan in the Philippine, on crop production, livestock, forestry and fisheries. The aim of this new application is to tackle some of the methodological issues raised in Section 4 and Annex 1 of this paper.

The RADAR approach can be further expanded, to host a statistically robust procedure for assessing the causal relationships between disasters and their impact on agriculture. This paper describes how to achieve this goal, using also the experience gained with FAO (2015) study.

2) *Scope of the FAO initiative*

The *geographic coverage* of the initiative is global: it should not be limited to developing countries; rather the focus should be global, and the experience of countries that successfully coped with disasters should be analysed in view of replicating it in other countries. The initiative will initially rely on six pilot countries. As discussed below, countries will be classified for the frequency of disasters, and the pilot countries will be selected among those with higher frequency, ensuring also the representation of all sub-sectors -- crops, livestock, forestry and fisheries. Pilot data collection can be implemented, for use within the RADAR framework, for the definition of damage and losses in agriculture, fisheries and forestry.

The initiative aims at obtaining specific, standardized and comparable data and metadata for monitoring damage and losses suffered by agriculture and their consequences in terms of food security conditions. Focus should be on the multiple threats that can impact the sector. The goal is gaining a more complete and comprehensive understanding of, and response to disasters and crises in agriculture.

This information system is meant to provide policy-makers, and stakeholders at large, with a sound information base for decisions making. Ideally, the information should allow implementing *ex-ante* cost-benefit analysis of prevention as well as *post-disaster* resource allocation. Importantly, the analysis of data on historical events, combined with information from early warning systems (e.g. GIEWS, EMPRES, IPC tool) could improve anticipation of disaster impact, and support actions to be taken before, during and in the immediate aftermath of an event.

In terms of scope, the initial focus of the initiative is going to be on disasters triggered by natural hazards, following the approach of the FAO (2015) study. The scope however will be gradually widened to include more types of hazards and shocks, taking advantage of the flexibility of RADAR's framework. Through time, the initiative should include:

a) Natural hazard-induced disasters (e.g., geophysical and climate-related disasters - droughts, floods, fires, landslides, volcanic eruptions, tsunamis, earthquakes, storms, extreme temperatures, hailstorms, etc.). Among these, particular attention should be devoted to silent, neglected disasters, intensely affecting a limited number of people. Note that such a degree of precision entails the need to improve data calibration within the RADAR framework.
b) Food chain emergencies of transboundary or technological threats (e.g., transboundary plant, forest, animal, aquatic and zoonotic pests and diseases, food safety events, radiological and nuclear emergencies, dam failures, industrial pollution, oil spills).
c) Man-made disasters, such as conflicts and civil unrest[5].

In fact the difference between natural hazard and human-induced disasters is not clear-cut. Disasters triggered by natural hazards bear variable consequences depending upon human behaviour and human environment in which they occur. Typically, damage and losses from droughts and floods can vary considerably depending on the level of investment in mitigation and adaptation in the affected regions (Vogel et al., 2007; Shreve and Kelman, 2014). All disasters impact, therefore, are dependent on the socio-political framework to some extent[6].

3) *Expected outputs*

The initiative will deliver two main products.

- First, **a periodic report** will be produced – possibly bi-annual – taking stock of the main disastrous events that affected agriculture around the world, with a special emphasis on poor regions and fragile economic and social environments. Initially this will be based mostly on secondary data, and be conceived as a follow-up and a refinement of the FAO (2015) study for computing damage and losses in agriculture, and RADAR for linking the magnitude of the disaster and its impact in agriculture. The first report will assess medium and large scale disasters that occurred in 2014 and 2015. The report will also include a selected case study concerning human-made disasters, as well as a case study on disaster impact assessment using the RADAR procedure. In the medium-run, the report may contain a more standardized monitoring part, which disseminates information on what happened during the recent years, and a more specialized thematic

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[5] In this case quantifying damage and losses does clearly make sense only *per se*, and not for the purpose of comparing them with benefits from investment in prevention.

[6] Based on DRR good practices and resilience, all disasters are man-made in the sense that, for instance, a low level of investment in disaster risk management might increase the impact of disasters.

part, dealing with one specific major event or a topic in the area of disasters and agriculture. Through time, the monitoring part would be using decreasing amounts of secondary data, and be increasingly based on first-hand information from the national and possibly sub-national level.

- Second, the initiative will gradually move toward **building an information system** based on primary data on damage and losses from disaster in agriculture and their consequences on food security. This transition will eventually feed the RADAR framework with model's calibration, and allow using more accurate estimation models of disasters impact. This system will be built in steps, starting from national level pilots. The information should be based on a limited number of indicators, to be collected at national and sub-national level, indicating the presence of the disaster and the extent of the associated damage and losses. Data from this system should also be analysed and disseminated in the periodic report discussed above, and constitute the backbone of the monitoring system in the medium run.

The initiative will take into account to the extent possible:

- Sub-sectors: a thorough analysis of fisheries and forestry subsectors is required – this includes the consideration of their different timeframe compared to crops and livestock;
- Multidimensionality within subsectors: for instance, the study of relation between the magnitude of the disaster and subcomponents of the agricultural output (crop production, land use, facilities etc.), and its pattern through time.
- Damage and losses across economic sectors: spill-over effect from agriculture, fisheries and forestry should be considered, starting from those affecting food production chains;
- National and sub-national data;
- Seasonal data.

The periodic report will be built in its initial phase, as a generalization of the work initiated with the FAO (2015) study and a systematic application of RADAR. The report will thus contain an *ex-post* assessments of disasters impact based on secondary data. At the same time, the information system will be piloted in a set of countries, experimenting on collecting primary information on the impact of disasters in agriculture. Building the information system will require further development of methodology and the identification of a set of indicators that can be monitored at national and possibly sub-national level. Through time, the information system is expected to increasingly supplement the *ex-post* assessment of damage and losses included in the periodic report.

4) Three logical steps for building an information system

The information system will constitute a generalization of the *ex-post* assessments reported in the FAO (2015) study, and also an attempt to provide more detailed and timely data, meaningful for RADAR implementation. The proposed information system involves three logical steps.

1. The identification of disasters, which has to detect the presence and size of a disaster.

2. The identification of the causal linkage between the identified disasters and damage and losses in agriculture.
3. The assessment of the damage and losses in agriculture following from disaster, which will also constitute a measure of its potential impact.

These three elements can be represented by a list of sets and functions, which facilitate the identification and separation of the conceptual steps (see Annex 1).

For the first step, the FAO (2015) study uses the number of persons affected, based on external information sources on disaster. While this is a useful starting point, it may fall short of identifying disasters that do affect a limited number of persons in a very severe way, and more in general those that do not make enough casualties to be noticed outside agriculture. The second step is virtually absent in the FAO (2015) study, which simply observes an association between yield declines and the occurrence of a general disaster. While the decline is likely to be related to the disaster occurred, its causal relation with the change in agricultural production is not known. In fact this may be complex, as it may involve changes in land allocation, in the availability of inputs and in production costs, which may trigger substitutions among activities. Hence the production mix may change, along with market prices. As for the third step, the identification of causal relationships between disasters and their impact on agriculture would allow a more precise estimation of the impact of disasters, thereby limiting the risk of under- or over-estimation to the extent possible.

Besides the evaluation of damage and losses in agriculture, given the role and position of FAO with respect to food security monitoring, it would be a low-hanging fruit for this initiative to also provide information on the impact of disasters in terms of food security. The FAO (2015) study does this by considering declines in the availability of calories as result of post-disaster production losses, calculated as share of per capita Dietary Energy Supply (DES) at the national level. The information system could also improve on the timeliness and accuracy of this type of information.

In the following section, the knowledge available on each of these steps is described. The literature on this topic is largely based on econometric techniques and simulation models that can be used to represent complex relations within and outside agriculture, fishery and forestry. The information system will likely not be able to rely on such tools. What can be piloted at country level is probably a limited set of indicators (see section 6), which should be able as much as possible to capture the complexity of the picture.

5) Available knowledge

A number of studies have analyzed the three steps highlighted above. These are reviewed in the following three sub-sections; more details are in Annex 1. Moreover, Annex 2 includes an extensive list of available data sources that might (initially) populate the dataset of the information system.

5.1 Identifying a disaster

Major contributions from the literature in this field come from the studies of natural hazards, and particularly weather shocks. Weather shocks estimation studies propose different functional forms for the appropriate identification of (natural) disasters. The new climate-change economy literature (Dell, Jones and Olken, 2014) focuses on changes in weather realizations over time, within a given area. There are four steps in the identification of disaster.

- First, the type of hazard has to be defined and data have to be collected accordingly, for instance, temperatures and evapo-transpiration variables for droughts or wind speed for hurricanes (Dietz et al., 2004). Both level and variability measures of climatic stressors variables (or indicators such as UNESCO aridity assessment ratio for drought, the Standardized Precipitation and Evaporation Index and the Agricultural Stress Index of GIEWS) should be taken into account but the timeframe should be defined beforehand.
- Second, the researcher should choose a functional form for the function that links the stressors to the definition of the hazards.
- Third, robustness must be performed along multiple dimensions: time, spatial location, position and number of thresholds (if applicable).
- Finally, weather data should be aggregated to an economically meaningful level. There are two potential approaches commonly used in the new-climate economy literature: the first is to aggregate spatially through area-weighted average of weather variables; the second is to aggregate using population weights. Which method to use depends on the framework: the former is more appropriate for agriculture production while the latter fits with productivity analysis (e.g. labour productivity).

5.2 Linking a disaster to its consequences in agriculture

A major contribution throughout the existing literature for the estimation of weather impacts on the economy comes from the Integrated Assessment Models (IAMs). These models combine information from different disciplines. In the climate change literature, they have been used to jointly analyze scientific and socio-economic aspects of climate change, in view of formulating and assessing the consequences of policy options. Examples include the DICE/RICE models, PAGE model, FUND model, the IMAGE and the ENVISAGE.

Our focus is on damage functions that specify how (weather) shocks affect an economic activity (notably agriculture).

The weather literature can help calibrating magnitudes of the effects of potential disasters, i.e. calibrating IAMs. This type of modelling could be flexible enough to incorporate short run shocks and their dynamics, which might be an important element for continuously exposed regions. However, not all existing IAMs lend themselves to this kind of use; hence the responsiveness of IAMs to such shocks should not be taken for granted, and would deserves careful testing.

As extensively described by Dell, Jones and Olken, 2014 the early debate over the likely impacts of extreme, short-run weather events on agriculture was characterized by three econometric approaches. Production function approach relies on the specification of an ex-ante relation between the climate and agricultural output. This estimate is consequently used to simulate impact of a potential disaster (Rosenzweig and Iglesia, 1994). Although the calibration of the model is based on experimental data, the main critique by further studies is related to the difficulty in properly modelling real farmer behaviors (e.g. the adaptation switch to new crops).

Cross-sectional regressions analyze land values (e.g. farm land prices) to recover the net impact of the shock on agriculture. This approach is called ‘Ricardian’ and has been pioneered by Mendelsohn et al., 1994.The major critique comes from Schlenker et al., 2005 underlining the critical role of risk reduction assets, notably irrigation in the hedonic approach.

Panel estimates are based on year-to-year with-in spatial area variations. Panel studies allow to isolate the (weather) shock from many others potential idiosyncratic factors that are correlated with it. This branch of the literature is broad. For instance, Schlenker and Lobell (2010) use weather fluctuations to estimate a model of yield response in sub-Saharan Africa; Yang and Choi (2007) tested international remittances response to rain shock. Panel data are also used to estimate ‘adaptation’ (Burke and Emerick, 2013) and mitigating mechanisms in agriculture, such as irrigation (Fishman, 2011) or migration (Munshi 2003). Finally, fixed-effects model with quadratic terms are used to study nonlinear effects (Lobell, Schlenker and Costa-Roberts, 2011).

5.3 Assessing the consequences in agriculture

The third step described above is the assessment of the damage and losses in agriculture following from the identified disaster.

The different type of models employed to analyze the causal link between a stressor variable and the consequences in terms of agriculture – the damage functions included in IAMs, the production functions and panel estimations – can in principle be used to quantify damage and losses, both with *ex-ant*e predictions and *ex-post* realizations of the stressors. As mentioned their ability to provide correct answers depends upon the time frame of the data that they employ, and should be carefully assessed.

The other consolidated methodology available for assessing in detail the impact of a disaster on agriculture is the one whose results are reported in the FAO (2015) study, in its review of 78 Post-Disaster Needs Assessments (PDNAs). As mentioned, in addition to the PDNA review, the FAO (2015) study assesses production losses after natural hazards based on the analysis of yields and production trends. The main methodological insights come from the Damage, Loss and Needs Assessment by the GFDRR (2010), which evolved into the Post-Disaster Needs Assessments (PDNAs) conducted jointly by the World Bank, United Nations and national Governments. The UNISDR (2013) loss data and risk analysis, and the joint WFP and FAO (2009) CFSAMs provide more specific information on agriculture and food security. A similar approach characterizes Warner et al., 2013 report from UNU-EHS with the support of the African Climate Policy Centre (ACPC).

One main take-home message from this literature is the need to distinguish *direct damage*, i.e. total or partial destruction of physical assets existing in the affected area, from *indirect losses*, i.e. changes in economic flows arising from the disaster. In the PDNA methodology (replacing the DaLA methodology by broadening it), the size of damage is calculated as the actual value of damaged assets, based on the replacement value (e.g., for soil, irrigation system, infrastructure), or by the prevailing market price (e.g., for agricultural machinery, equipment, stocks). For perennial crops, damage is equal to the cost of replanting. Computations of opportunity costs should refer to pre-disaster prices. Agriculture-related assets are sub-sector specific. In particular, crop-related assets include soil, irrigation systems, agricultural infrastructure, machinery, equipment, input stocks and perennial plantations; livestock-related assets include animals, pasture, sheds, storage buildings, stored feed and fodder beyond equipment and machinery used for livestock; fisheries assets include fish and/or shrimp ponds, hatcheries, fish fry and fingerlings, freezers and storage buildings, fish and fish feed, engines and boats, fisheries equipment; forestry assets include, among others, standing timber, firebreaks and watch towers, forestry equipment and machinery, fire management equipment. The size of losses is calculated as the deviation in levels of the agricultural output in the year of the disaster with respect to a “normal” year or to pre-disaster forecast when available. The definition of “normality” is still controversial: for example, the opportunity cost might be calculated through ex-ante market prices. Moreover, estimation of losses computed as the deviation of agricultural output from the baseline might poorly identify the impact of the disaster per se. The main issue relies on omitted variable biases due to idiosyncratic shocks such as civil conflicts, political instability or global macroeconomic shock (e.g. international food prices crisis).

Another take-home message from these studies is the need to separate the assessment of the impact by sub-sector: crops, livestock, fisheries and forestry. The choice is mainly driven by different data needs and availability, while the methodological approach is similar.

In the climate change literature, Dell, Jones and Olken (2014) claim that the vast majority of existing studies focus on yields as agricultural output. In particular, the log of agricultural revenue per acre from specific crops (Burke and Emerick, 2010) and agricultural land values (Deschênes and Greenstone, 2007) are widespread variables used throughout past studies. Overall, the literature agrees in the use of a monetary metric to assess both damage and losses in agriculture.

In fact there is a high degree of overlap between the literature on the post-disasters assessment and the (broader) literature that studies the causal relations between agricultural output and disasters, notably weather variables. For instance, yields are a well-grounded outcome variable also in the study of the causal effect of natural hazards (largely weather variables) in agriculture (Schlenker and Roberts, 2009).

For our purpose, however, it is useful to maintain a separation between these two elements, as the aim of the activity is largely on the former – i.e. producing data on both disasters and idiosyncratic agricultural damage and losses – rather than on the causal relation per se.

However, causal relation between disasters and their consequences do play a role when it comes to using disaster assessment as a mean to plan investment in prevention.

Agricultural prices might also provide informative indicators of macroeconomic changes in the agricultural sector, correlated with disasters. Moreover, data availability is relatively high. In particular, Dell, Jones and Olken (2014) highlight the tight interaction between of adjustment of prices, conditional of their elasticity, and factor reallocation due to extreme weather events.

In summary, there seem to be two options for a quantitative assessment of damage and losses in agriculture. First, a *model-based assessment*, which can quantify the consequences of disasters via damage fuctions across economic sectors -- including agriculture -- and on different variables simultaneously (eg production, prices, incomes, welfare, trade). Second, a *non-model-based, direct assessment* of damage and losses. In essence this would be an application of the PDNA methodology at country level, possibly with a large number of details on agriculture. Much specific technical expertise in these areas is required for defining and prioritizing the indicators to be collected in both cases. The model-based exercise appears more centralized: while appearing analytically more complete, it would inevitably be more research-oriented. The second option is based on simplified conceptual framework, which takes into account as much as possible the available implemented and owned at country level. Although more limited in scope, this option can be more easily translated into a set of indicators to be piloted at country level, which would still require much expertise. The two exercises are not mutually exclusive. In fact, they can be considered complementary: for instance, the non-model-based tool can be used at early stages and inform the system for calibrating the model-based exercise.

6) A set of indicators

In line with the available knowledge and the conceptual framework presented above, the complexity of each of the three steps highlighted above should be simplified by identifying a set of indicators that can provide enough detail on disaster impact on agriculture, while at the same time be manageable for the existing data collection systems at national and subnational level.

Two main categories of indicators should be identified and piloted.

1. Indicators of disasters. These should allow classifying different types of disasters. The idea is to develop indicators that also identify events that bear acute consequences for a limited number of persons - the so-called “silent disasters”.
2. Indicators of disasters’ impact. In turn these include:
    - Indicators of disasters’ costs. These indicators are used to quantify the impact of disasters in monetary terms. They should be divided into two sub-categories:
        i. Indicators of direct damage, e.g. value of damaged assets.
        ii. Indicators of indirect losses, e.g. value of production losses, income losses and other economic losses.
        iii. Indicators of food security conditions.

- A comparison of disasters' costs with disaster-related *ex-ante* investments

The system should start from providing the required information in physical terms, notably losses and damage in terms of foregone production, assets destroyed and increased food insecurity. But it should allow computing value entities, using a *money metric*. This will enhance comparability across time and space, while allowing the comparison of benefits and costs as specified above.

As possible, it would be useful also to compare disasters' costs with investment in risk reduction, climate change adaptation and other prevention activities and strategies, including the avoided costs of disastrous events. It is probably difficult to undertake such comparison on the basis of global data and with homogenous criteria across countries. However, country case-studies could be commissioned, which may provide for examples of this comparison with reference to specific events.

Indicators needed to identify disasters must be disaster-specific, as envisaged in the RADAR framework. Hence, the first step should consist in agreeing upon a classification of disaster and those that the system will focus on.

A limited set could be targeted at the beginning. While the number of persons affected (as both absolute number and share of total population) or the presence of an international call could still be used for large and evident disasters – for which an identification based on people affected may work reasonably well – rainfall and temperatures can probably be considered as additional indicators for flagging "silent" disasters.

Depending on the disaster, other indicators that may be considered include wind speed, Normalized Difference Vegetation Index (NDVI), Standardized Precipitation Index (SPI), share of (aquatic) animal or (forest) plants affected by transboundary pests and diseases (EMPRES besides Fisheries and Forestry FAO division).

All these indicators would allow identifying disasters without relying just on their impacts. This means that, besides being able to track "silent" disasters, it would be possible to compare disasters with the same impact but different intensity – say, according to the amount of rainfall – and understand the drivers of such divergence, including a different level of preparedness or resilience. A detailed list of indicators should be built across specific activities, including crops, livestock, fisheries, forestry.

This procedure for detecting disasters based on (climatic) stressors has the main drawback of being very sensitive. It might be the case that there is no perfect correspondence between climatic stressors peaks and the presence of a disaster: in fact, there is an obvious fluctuation of these stressors that is 'normal' and not due to some natural hazard. However, efficient techniques for tracking rumors in the stressors' time series can allow a reliable tool for identifying climatic shocks. While using the number of people affected is suitable only for medium-to-large scale disasters, the use of exogenous stressors might also flag 'silent' disasters. This initiative should explore both possibility and their coexistence. In particular, large scale (natural) hazards, detectable with both methods, can be the common ground for calibrating the sensitivity of the stressors. In line with the stressor procedure, the use of NASA data from satellite imagery can be very informative for the set of indicators of disasters.

Concerning **disasters' impact** the "indicator" is a simple monetary value of the sum of damage and losses. Such values should be conveniently reported through time, with discount rates, and space, through a uniform international currency.

Some methodological criteria for the assessment can be described as follows.

> **Damage.** These require an assessment of the number of units of damaged physical assets. These will have to be assessed in terms of replacement values, that is, the current cost of re-building the asset. For annual crops, data needed are: reference values for land, irrigation system and infrastructures, irrigation equipment (e.g. engines, electric motors, pumps), storage facilities, stored agricultural inputs, farm buildings and sheds, farm equipment and machinery, internal farm roads, perennial trees (e.g. plantations). For perennial crops, damage should be assessed in terms of the cost of replanting. For livestock, damage should take into account the quantity and quality of physical assets: animals, pasture, livestock sheds, storage buildings, stored feed and fodder, livestock equipment and machinery. For fisheries, damage should take into account assets such as fish and/or shrimp ponds, hatcheries (fish and/or shrimp), fish fry and fingerlings, freezers and storage buildings, fish and fish feed, engines and boats, fisheries equipment. For forestry, assets should include, among others, standing timber, firebreaks, watchtowers, forestry equipment and machinery, fire management equipment. In valuing damage, discounted values should be used with reference to the periods required to rebuilding or repairing each damaged assets. Fixed summary rules should be identified for each group of assets, to facilitate the estimation.
>
> **Losses.** For annual crops, losses should be estimated first in physical terms, as the difference between an expected production prior to the disaster and the actual production in the disaster year. To obtain corresponding values, the expected production prior to the disaster should be assessed with a pre-disaster expected price, while the post-disaster production should be valued with the post-disaster values. It would also be useful to compute a loss at constant prices – say valuing both pre- and post-disaster production with pre-disaster expected prices, to obtain a summary measure of the quantity loss. For perennial crops, production losses should also be considered in terms of the lost flow of production in future years, until replacement is complete. The same criterion should apply to livestock production and forestry products. Adding the time dimension will trigger the use of discount rates on prices.

Data for conducting the above assessment may come from different sources, including both traditional field sample surveys and advanced technologies such as mobile phones, satellite remote sensing and possibly crowdsourcing.

As for the indicators of **food security**, this initiative will investigate the impact of disasters on food security conditions, as a subset of consequences. While the PoU and the change in the availability of calories employed in the FAO (2015) study can provide an effective *ex-post* picture, in setting up an information system it is necessary to consider more timely and more specific indicators.

One option in this filed would be to link the pilot data collection to the Integrated Food Security Phase Classification (IPC, 2012) project. This allows classifying the severity of conditions on the ground based on a consensus building process, which uses available data.

Another option for obtaining timely assessments of change in food security condition is offered by the experience-based indicators, notably those collected through the Food Insecurity Experience Scale proposed by the Voices of the Hungry project. These indicators allow a direct measurement of people’s ability to access food through 8 questions, which may be easily administered even under immediate post-disaster conditions.

Finally, it should be considered that the consequences of disasters in terms of food security conditions should be carefully interpreted in light of the resilience conditions. Hence having an idea of the resilience conditions of disaster-prone areas may facilitate both the assessment of the consequences and, especially, the assessment of the investment required for reducing them. The Food Security Information Network (FSIN) Technical Series (2014) proposes a harmonized methodology for measuring resilience to food insecurity through an econometric structural equation model. Moreover, a comprehensive analysis of the impact of shocks on food security requires a battery of indicators on pre-post vulnerability (e.g. existing insurance mechanisms or social and financial protections) and DRR good practices (e.g. FAO ongoing inventory) that should provide key insights for this purpose (see FAO Resilient Livelihoods, 2013).

In agriculture, the multidimensional concept of resilience can be summarized through indicators such as crop diversification, appropriate crop selection, adjustment of cropping calendar, crop insurance, and seed systems that are all suitable indicators. For livestock, the presence of shelters, fodders reserves and conservation, animal vaccination, agro-silvopastoral system diversity can be considered. For fisheries indicators can include infrastructure and fisheries insurance, safety for fishing vessels and aquaculture biosecurity.

7) Institutional framework

The preparation of the periodic report based on the *ex-post* assessment, following the methodology of the FAO (2015) study for measuring damage and losses through a money metric, and starting from RADAR framework for linking disasters magnitude to their impact in agriculture, fisheries and forestry can be done in FAO – at least for the first issue – with a centralized team. The piloting of the information system, instead, will require a highly decentralized organization, involving counterpart institution in member countries. These institutions will also contribute to the validation of the secondary source data published in the periodic report.

Primary counterparts for piloting the collection of data and the assessment of damage and losses are expected to be Ministries of Agriculture and National Statistical Offices. Public and private insurance schemes should be also considered as potentially relevant counterparts; they may both support data collection and share data they already maintain. To be sustainable, activities should ensure buying-in from national counterparts and consistency with ongoing statistical work within national and sub-national institutions. This will lead to the development of information systems that countries can be up-scaled and sustained through time.

Pilot countries should be identified among those where disasters have a high impact on agriculture and livelihoods and where the governments have expressed interest to invest in emergency-related information systems. A first exercise, which could also be reported in the first periodic report, would be a statistical analysis aimed at identifying countries that are relatively more disaster-prone. A sub set of these could be involved in piloting assessments and data collection. As mentioned, the initiative can focus, at its early stages, on the medium and large-scale disasters that affected developing countries in 2014 and 2015, along the line of the FAO (2015) study. A case study on conflict-affected protracted crisis will be included in the first report in order to broad the type of disasters to civil conflicts.

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Annex 1. A description of the steps involved in the information system

The intuition underlying the proposed three-step structure is as follows. Given

- a set of a stressors W (e.g. a set of weather variables);
- the presence (and eventually the size) of the disaster S (e.g. a weather shock);
- a set of consequences of the disaster C (e.g. outcomes in agriculture)
- a function which associates stressor variables to the presence and/or size or the (natural) disaster $f: W \rightarrow S$
- a consequence function, which associates the disaster to the outcomes in agriculture $v: S \rightarrow C$
- a monetary function which associates to consequences (outcomes) a monetary value $m: C \rightarrow \mathbb{R}$ is.

one can say that

(1) $$W \xrightarrow{f} S \xrightarrow{v} C \xrightarrow{m} \mathbb{R}$$

The three functions *f*, *v* and *m* have to be analyzed separately, and they correspond to the three logical steps highlighted above.

The identification strategy to detect the presence and size of a disaster can be represented by

(2) $$E_1 = \langle W, S, f \rangle$$

or environment E_1, which studies the way of detecting and measuring a (natural) disaster, based on the stressors available *W*, through function $S = f(W)$.

The causal link between disasters and their consequences in agriculture is represented by environment E_2, which studies the mechanisms linking disaster *S* to damage and losses, and the causal relation.

(3) $$E_2 = \langle I, S, d, l_1, l_2, v, (A_i)_{i \in I} \rangle$$

where:

A_i is a set of characteristics of *i* (e.g. agricultural assets, political environment, geographical area, etc.)

$d: S \ x \ A_i \ \rightarrow \ D_i$ is a function linking the shock to damage D_i, depending on A_i

$l_1: S \ x \ A_i \ \rightarrow \ L_i$ is a function linking the shock to losses L_i, depending on A_i

$l_2: D_i \ \rightarrow \ L_i$ is a function linking damage D_i to losses L_i

$v\big(d, l_1, l_2(d)\big)\colon \ S \mid A_i \ \rightarrow (D_i, L_i)$ is the consequence function, conditional on A_i

The strategy to assess damage and losses can be represented by environment E_3,

(4) $$E_3 = \langle\, I, m, (D_i,\ L_i, C_i)_{i\in I} \rangle$$

where:

$I = \{1,2, \dots ,n\}$ is the set of observational units (e.g. countries, regions) denoted by i

$C_i := (D_i, L_i, F_i)$ is a sequence of three objects for each observational unit i: damage (D_i), losses (L_i) and food security status (F_i)

$m\colon C_i \rightarrow \mathbb{R}$ is the monetary function associating each pair (D_i, L_i) to a monetary value, ∀ i

Environment E_3 studies the way of transforming direct damage and indirect losses into monetary values throughout the procedure $m(C_i)$.

Note that from the disaster function *f*, the consequence function *v* and the monetary function *m*, we obtain a function that assigns to each disaster condition W, a monetary value $m\big(v(S)\big)$ of consequences of disaster *S*, where $S = f(W)$, for each observation unit *i*.

We call this function value function u_i.

$$u_i = m\ \Big(v\ \big(\, f(\cdot)\big)\Big):\ \ W \mid A_i \rightarrow \mathbb{R}$$

This general formulation of the environment describes the link between the climatic stressors *W* and its consequences in terms of monetary value – as given by u_i, given the characteristics of the observational units A_i.

As described when introducing identification techniques for (natural) disasters, in order to define environment E_1, past studies in climate change literature have developed a two-step-procedure definition. First, the intensity of the shock has to be assessed. There are three common approaches for modelling the relation that associates stressor variables to the presence and/or size or the disaster; these correspond to functional forms for function *f* in equation (1).

The *levels approach*: in a panel set up, the size of the shock comes from the deviation in levels (e.g. degrees in Celsius for temperature or millimeter of precipitation) from the within spatial area historical mean (Dell, Jones and Olken, 2014). The main limitation of this approach concerns its dependency form the functional form. For instance a logarithmic form might be used, in which case the identification takes the form of percentage deviations.

The *frequencies approach*: the intensity of the shock depends on the frequency at which the weather realization falls into different bins (e.g. pre-specified degree ranges) (Deschênes and Greenstone, 2011). The method is non parametric but needs high-resolution data because extreme weather events might be averaged out in aggregating across either space or time.

The *anomalies approach*: the intensity of the shocks corresponds to the level difference from the within-spatial-area mean, divided by the within-spatial-area standard deviation

(Barrios, Bertinelli, and Strobl, 2010). For this approach to be meaningful long-run standard deviation (the literature agrees that 30-year time series as confirmed by the World Meteorological Organization - WMO) is required. However, data noise might cause a major problem.

These three approaches are implementable on the basis of statistical analysis, or on the basis of expert judgment. Statistics can be used to identify what realizations of the disaster variable constitute a large enough deviation from the expected value. An expert judgment can also lead to the definition of a threshold, based on the specific knowledge. Examples are biological information on the relation between crop growth and temperature, which are known for a number of crops (Schlenker and Roberts, 2009).

Second, based on the size of the shock, a decision must be taken on what intensity of the shock defines a disaster. There are two options for this step. As a first option, one could choose whether to focus on a shock of a certain size only, by specifying a threshold above which the potential disaster is considered as an outlier, and hence the disaster has ‘occurred’; this corresponds to using a dummy structure. Medium-to-small scale (silent and neglected) disasters might get excluded, even if they have significant economic impacts in exposed areas with vulnerable population. This limitation strongly depends on data resolution. For instance high-resolution data across time might allow detecting silent disasters.

Another option is to study a large range of disasters, and establish a link between their intensity and economic consequences. In this case, both gradual changes in stressors and extreme events can be identified along a continuum. While this is a practical way to address the difficulties associated with the identification of disaster, in terms of methodology highlighted above it becomes more complex to identify disasters. The heterogeneity of possible consequence from disasters may lead to overlooking significant natural hazards because of a small net impact on agriculture, despite substantial changes in the stressors.

Moreover, the first option – the dummy structure – requires a set of robustness checks, to verify that results are not an artifact of the threshold chosen. The second option – the link with the final outcome – is exposed to the high level of noise from data, due to measurement errors, which calls for complex econometric techniques.

The reliability of the results of this step, as usual, depends heavily upon the on the availability of data on potential disaster variables – in the literature these are mostly geo-climatologic data – and their quality. A general indication from the literature is that it is convenient to choose the most general functional forms if agnostic about the specific model (Dell, Jones and Olken, 2014).

This procedure represents a theoretical framework adaptable to a vast variety and sizes of disasters, although specificities of each category of (natural) disasters imply differences in the implementation. It represents a step towards harmonization for many types of hazards, geographical areas and agro-ecological zones.

Annex 2. Available data sources

Also this section in organized along the two steps highlighted above, that is, first the data on that allow the identification of the disasters is described, and then the data that can be used to assess the consequences in terms of damage and losses. In fact the data that are required to assess the consequence show a high degree of overlap with those that describe the causal relation between disasters and their consequences. Data that can support step two and three of the methodology, in other words are the same.

A2.1 Data for identifying disasters

The proposed framework should build as much as possible on existing data and indicators. Several organizations and research institutes provide access to datasets that could be used for the identification of natural hazards. Depending on the goals and objectives of the analysis, different types of data can be used to identify past disasters, monitoring climate trends, and predicting the likelihood of disaster occurrence. The following are examples of datasets that can be used and combined to inform this methodological step.

> *Emergency Events Database of the Centre for Research on the Epidemiology of Disasters (EM-DAT CRED)*. EM-DAT contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. It provides information especially on the type of disaster and the number of people affected (deaths, injured, affected, homeless, total affected), as well as on the total monetary damage (although data on damage is very limited). This dataset can be particularly useful tool to calibrate the methodology for disaster's detection, provided the related information system (secondary data in the first place to move to primary data after).
>
> *Agricultural Stress Index System (ASIS)*. ASIS's main goal is to monitor drought events and their impact on cropland. It is based on 10-day (dekadal) satellite data of vegetation and land surface temperature from the METOP-AVHRR sensor at 1 km resolution. ASIS allows countries to fine-tune parameters of the system based on detailed land use maps and national crop statistics. It is based on the Vegetation Health Index (VHI) derived from the Normalized Difference Vegetation Index (NDVI).

These two data sources allow identify disasters directly. The following ones, instead, only provide raw data on variables (e.g. precipitations) that can be used for identifying disasters based on some of the techniques described in the last section and in Annex 1.

> *Global Historical Climatology Network (GHCN) Ground station data*. The dataset contains daily records from over 80,000 stations in 180 countries and territories, and its processing system produces the official archive for U.S. daily data. Variables commonly include maximum and minimum temperature, total daily precipitation, snowfall, and snow depth; however, about two-thirds of the stations report precipitation only (Dell et al., 2014).

University of East Anglia, University of Delaware (UDEL), NOAA GHCN_CAMS. One important challenge posed by ground station data is their incomplete coverage, particularly in poor countries or areas with sparse population density. As a result, climate scientists have developed a variety of gridded data products, which interpolate among the ground stations. An example is the global temperature and precipitation data produced by the Climatic Research Unit (CRU) at the University of East Anglia and by Willmott, Matsuura, and Legates (2010) at the University of Delaware (UDEL). Both have a spatial resolution of 0.5 Å~ 0.5 degrees but the station records and extrapolation algorithms used differ somewhat. CRU contains data on monthly minimum and maximum temperature, while the Delaware data provides the monthly average temperature. NOAA GHCN_CAMS Land Temperature Analysis, and the Global Precipitation Climatology Center provides gridded precipitation data (Dell et al., 2014).

Climate Data Records (CDR) of the University of Alabama Huntsville. The UAH satellite temperature dataset uses remote sensing systems (RSS) to infer the temperature of the atmosphere at various levels from satellite measurements of radiance. A set of algorithms and procedures are used to infer Mean Layer Temperatures (MLTs) for the lower troposphere (TLT), middle troposphere (TMT), and lower stratosphere (TLS), using the Microwave Sounding Unit (MSU) and the Advanced Microwave Sounding Unit (AMSU).

NCEP/NCAR Reanalysis Data. The NCEP/NCAR Reanalysis Project is a joint project between the National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCAR). The goal of this joint effort is to produce new atmospheric analyses using historical data (1948 onwards) and as well to produce analyses of the current atmospheric state (Climate Data Assimilation System, CDAS). A large subset of this data is available from PSD in its original 4 times daily format and as daily averages.

ECMWF's MARS Archive. The Meteorological Archival and Retrieval System (MARS) of the European Centre for Medium-Range Weather Forecasts (ECMWF) provides data on forecasts, climate re-analyses, reforecasts and multi-model data. Data have high resolution and are based on satellite measurement and reanalysis data.

Global Observing Systems Information Center (GOSIC). The GOSIC Portal serves as a clearinghouse providing convenient, central, one-stop access to data and information identified by the Global Climate Observing System (GCOS). The GCOS is a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate system, for detecting and attributing climate change, for assessing the impacts of climate variability and change, and for supporting research toward improved understanding, modelling and prediction of the climate system. The GCOS addresses the total climate system including physical, chemical and biological properties, and atmospheric, oceanic, terrestrial hydrologic, and cryospheric components.

FEWS NET Data Portal. The USGS FEWS NET Data Portal provides access to geo-spatial data, satellite image products, and derived data products in support of FEWS NET monitoring needs throughout the world. This portal is provided by the USGS FEWS NET Project, part of the Early Warning and Environmental Monitoring Program at the USGS

Earth Resources Observation and Science (EROS) Center. Data is organized by region. To support the use of data for decision-making, a set of tools were developed and linked to the data portals. These include (1) Interactive map viewers; (2) Early Warning Explorer; (3) Geospatial water requirement satisfaction index; (4) Geospatial Stream Flow Model (GeoSFM); (5) Decision Support Interface (DSI).

The idea of moving beyond the analysis of natural hazard situations and assess, for instance civil conflict and conflict-affected protracted crisis, brings into the picture the need of related data sources such as:

Heidelberg Institute for International Conflict Research (HIIK). HIIK use five intensity levels of political conflict, i.e. dispute, non-violent crises, violent crises, limited war and war. A dataset is publically available with intensity values of all conflicts in 2014, plus other basic data (http://www.hiik.de/en/downloads/#dataset_2014). Some regional monthly intensity (RMI) data and mapping are also available.

Peace Research Institute Oslo (PRIO) (https://www.prio.org/Data/Armed-Conflict/) likely to be of most interest is ACLED (http://www.acleddata.com/) which gives locations, dates and additional characteristics of events, with ongoing data collection in Africa and S/SE Asia. Near real-time conflict data is updated monthly for all of Africa and weekly for 30 high-risk states. For Asia, ACLED includes data on eleven countries, updated monthly since start 2015.

Uppsala Conflict Database Programme provides a number of datasets that can be freely accessed, including the UCDP/PRIO Armed Conflict Dataset (http://www.pcr.uu.se/research/ucdp/datasets/).

IISS Armed Conflict Database (https://acd.iiss.org/). It is mainly analytical narrative, but also compiles statistics, which includes the status of conflicts (including intensity), fatalities, and number IDPs/refugees.

A2.2 Data for assessing the impact of disasters

Very limited data is available on the impact of natural disasters on agriculture. Specific information on damage and losses caused by disasters is often provided on a case-by-case basis, while little effort is done to organize global data in standardized information systems. Some examples of existing datasets and reports on disaster impacts are included in the following list. Both disasters data and visualization tools sources are reported.

Disaster Inventory System (DesInventar) is a conceptual and methodological tool for the construction of databases of loss, damage, or effects caused by emergencies or disasters. It provides access to 29 national databases covering Asian, Latin American and African countries (mostly LAC countries). A query system allows user to search for: Geography (regions and provinces); Types of events; Types of causes; Effects. Effects are reported by (1) Persons and property; (2) Sectors (including agriculture and livestock); and (3)

Economic Losses (including crops and woods losses, in hectares). Moreover, for what concerns agriculture, this database only reports damaged crops in hectares and livestock units lost. And as for the other indicators theoretically available, they are largely unreported. Recall that this database is informed by governments/national data.

AON's Annual Global Climate and Catastrophe Report. Annual report on Natural Disasters providing data on: Total events; Global Economic Losses; Global Insured Losses; Global Fatalities. The main limitation of this source is that it reports only total economic impact, while no specific information on agriculture is available. Moreover, the AON and other insurance companies reports only insured losses; the same applies to Munich RE and Swiss RE. None of these, moreover, report on losses in agriculture. The AON disaster detection is also based on a specific definition, which might not suite the purpose of the FAO initiative, as "natural disasters are defined as an event that meet at least one of the following criteria: economic loss of USD50M, insured loss of USD25M, 10 fatalities, 50 injured or 2,000 homes or structures damaged".

UNISDR's Global Assessment Report (GAR). This is a report published every two years, which provides data on lives lost and assets destroyed after natural disasters (although based on EM-DAT CRED database), as well as on investment in DRR. It made one attempt to estimates future losses and potential benefits of additional investments in DRR policies and technologies.

GFDRR's Post Disaster Needs Assessments (PDNA) from the United Nations, the World Bank and governments. Detailed assessments of monetary damage and losses caused by disasters, and recovery and reconstruction financial needs. More than 78 PDNAs are available for the past ten years, covering disasters in Africa, Latin America and Asia. More PDNAs are available for prior years.

Country assessment reports by WFP, FAO and other organizations. They are collected into WFP's Assessment Bank and they include, among others:

- *Crop and Food Security Assessment Mission (CFSAM)*. A Crop and Food Security Assessment Mission (CFSAM) is undertaken jointly by the Food and Agriculture Organization (FAO) and WFP, usually for emergencies related to agricultural production or overall food availability problems. It assesses the seriousness of a crisis situation, by looking at the food produced nationally and the extent to which poor people can meet their basic food needs.
- *Emergency Food Security Assessment (EFSA)*. An Emergency Food Security Assessment (EFSA) analyses the impact of a crisis on the food security of households and communities. An EFSA is conducted when a natural disaster, a conflict or an economic shock cause food insecurity due, for instance, to population displacements. An assessment can be triggered by a sudden event such as an earthquake or a flood or by a slow onset crisis, for example a progressive deterioration of the economic situation. The EFSA can be in the form of an initial

(6 to 10 days after the crisis), rapid (3 to 6 weeks after the crisis) or an in-depth (6 to 12 weeks) assessment.

Visualization platforms and data viewer are also available. These sources might be useful for the assessment of disasters by providing complementary information about risk and exposure of the economy to shocks.

GAR Risk Data Viewer. The global risk analysis presented in the Global Assessment Reports is based on a joint effort by leading scientific institutions, governments, UN agencies and development banks, the private sector and non-governmental organizations. This interactive Risk Viewer provides the global risk data from the Global Assessment Reports, presented in an easily accessible manner.

PREVIEW Global Risk Data Platform: The PREVIEW Global Risk Data Platform is a multiple agencies effort to share spatial data information on global risk from natural hazards. Users can visualize, download or extract data on past hazardous events, human & economical hazard exposure and risk from natural hazards. It covers tropical cyclones and related storm surges, drought, earthquakes, biomass fires, floods, landslides, tsunamis and volcanic eruptions. It provides information at country level.