Volta Flood and Drought Management

Methodology, stakeholders' contribution and future improvements of the Volta Flood and Drought Risk Profile

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Summary

This document provides a description of the scientific methodology for the elaboration of the Volta Floods and Drought Risk Profile, focusing particularly on the exposure assessment and data collection. The importance of data collection at local level is highlighted, both acknowledging the support provided by local technicians during the concluded elaboration phase and suggesting how the Volta Floods and Drought Risk Profile could be improved in the future with a key role of regional, national and local stakeholders.

Acronyms

AAL	Annual Average Loss
CIMA	International centre for environmental monitoring
GWP-WA	Global Water Partnership West Africa
OECD	Organisation for Economic Co-operation and Development
PML	Probable Maximum Loss
USD	United States Dollars
VBA	Volta Basin Authority
VFDM	Volta Flood and Drought Management
WMO	World Meteorological Organization

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Probabilistic risk profile in the Volta Basin: general approach

In the field of natural hazards, the concept of disaster risk introduces a series of different elements, which together contribute to determine it: Hazard, Exposure, Vulnerability and Capacity. Risk is given by the 'product' of a certain hazard and a human dimension, characterized in terms of vulnerability, exposure and capacity. Therefore, Risk Assessment involves the following steps [Douglas,2007; van Westen et al., 2011]: i) hazard assessment; ii) identification and characterization of exposed elements; iii) vulnerability and capacity assessment; iv) combination of previous steps and determination of the risk. This procedure is not standardized all over the world and different methods to determine each of these steps exist in literature and have been implemented in various tools and platforms for risk management.

In a probabilistic risk assessment, the risk is a product between a frequency and a certain loss. The link between these two quantities is represented by the return period-magnitude relationship that allows to associate a certain magnitude of the hazard to a certain frequency and - through the knowledge of the damage related to a certain magnitude - allows finally to know the link between the probability and the related loss.

The probabilistic risk can be seen as the evaluation of the damage caused by all possible scenarios, considering their associated likelihood. Each scenario, which represents one of all the possible realizations of the risk, is obtained through an event-based scenario modelling [Boni, 2010; Boni and Siccardi, 2011]. The event-based risk assessment, sometimes called deterministic risk [OECD, 2012], results in the reproduction of a certain event with some real characteristics. When approaching to a 'scenario' analysis, we are dealing with an imagined or projected sequence of events. In this case, it is not proper to talk about 'risk', since a probability assessment is not performed yet and it is preferable to name the result of this assessment as damage or impact assessment.

Flood risk assessment

In the methodology adopted within the Volta Flood and Drought Management (VFDM) project, which is implemented by WMO, VBA and GWP-WA and funded by the Adaptation Fund, the flood risk is evaluated as a combination of several damage scenarios. Thus, the overall approach entails the following steps:

- Hydrological simulation at basin level for the definition of series of water discharges in different locations of the basin, considering both current and projected climate conditions (according to pre-defined climate change scenarios).

- Geomorphological/hydraulic modelling for the evaluation of flood hazard maps – described in terms of maximum water depth – connected to the output of the hydrological modelling, for pre-defined return periods.

- The hazard maps provide water levels in flood prone areas for different return periods, but they do not represent flood events. In a complex and big basin like the Volta one, a flood event or flood scenario usually affects only a portion of the basin: to assess flood risk it is necessary to use all possible flood events that can affect the area in a certain period of time. Aim of the flood scenarios generation is the simulation of all the possible events that can affect different areas of the basin with different intensities.

- In a following phase, each flood scenario is characterized in terms of consequences, starting from the physical loss ratio of each exposed element; such a loss ratio can be obtained through the application of physical vulnerability curves, the choice of which depends on how the exposed elements are characterized and described.

- Once the physical integrity of the exposed elements is evaluated for the different considered exposed elements, further loss indicators – i.e. economic or social - can be evaluated through the integration of proper information.

- Based on the proper loss indicators, probabilistic metrics are used to characterize risk; more precisely, in this context AAL (average annual loss) and PML (probable maximum loss) have been derived for different indicators and for different administrative levels, from first subnational level to the overall basin.

Drought risk assessment

Drought disaster risk can be seen as the probability of experiencing harmful drought events with different severities of impacts over a certain period of time. These harmful impacts can be caused by a diversity of hydro-meteorological conditions that induce a less-than-average availability of water. The severity of drought impacts is also influenced by what is exposed to these conditions, as well as by the vulnerability of the exposed items to a reduction in water availability.

In the methodology adopted within the Volta Flood and Drought Management (VFDM) project, the overall approach for drought risk assessment entails the following steps:

- Identification of multiple impact severity categories (5% less than average yield, 10% less than average yield, 30% less than average yield, etc.) based on the observations of the variability in maize yields, a rain-fed staple crop that is quite sensitive to water shortages.

- Evaluation of hydro-meteorological conditions using drought indices, which can express the abnormality of the water available in the atmosphere (meteorological drought indices), hydrological system (hydrological drought indices) or the soil (agricultural drought indices), or in all three (combined drought indices), and thresholds to identify drought events.

- Use of machine learning techniques to identify hydrometeorological conditions that can lead to impacts on maize yield, assuming that this can be different per sub-national region, based on diverse vulnerabilities of different regions. This step results in a selection of drought indicators and their thresholds tailored to each region's characteristics.

- After identifying the hydrometeorological conditions that have led to observed drought impacts in the past, the probability of occurrence of such conditions is calculated, allowing to create probable maximum loss curves for reductions (-5%, -10%, -30%) in maize yield and to calculate the average yearly reduction of maize yield caused by drought conditions in relative and economic terms (USD).

- assuming that a reduction of 15% in maize yield indicates such severe drought conditions on the land that all people, animals and environment will be affected by it in one way or another (e.g. a shortage in food or fodder, losing income due to a distorted market, reduced health due to diminished water supply, reduced greenness in these areas etc.), the annual average people / livestock / protected area likely to be affected by droughts is derived for different administrative levels, from first subnational level to the overall basin.

Exposure data processing

Since the description and characterization of exposed elements is crucial for determining the final results of the risk analysis, it seems opportune to focus on how such elements have been considered within the project.

The scientific team carried out a training process on exposure and impact assessment to more than 60 national technicians (working in the national agencies in the field of hydrology, meteorology, disaster management, water resources, academia etc.), whose contributions – together with local institutions of the 6 riparian countries - were essential for the crucial process of local data collection, particularly for exposure assessment.

The focus here is to understand along which lines the results could be renewed or improved in future.

The proposed methodology evaluates the impacts on the following categories of exposed elements:

- Built-up area
- Population
- Essential services / infrastructures
- Agricultural and protected areas

For each of the considered exposed elements a series of available Global Datasets were used as a standard set for each Country within the basin. These datasets have the great advantage to have a global coverage and therefore to ensure a minimum background exposure knowledge to perform acceptable risk analyses, even in extremely data-poor contexts.

Nevertheless, these datasets usually offer a global coverage at the expense of a low resolution, both in terms of spatial scale and in terms of detail of the associated information. In order to improve the accuracy of the final risk assessment, a series of input data and knowledge from local stakeholders is needed, as it graphically shown in Figure 1.

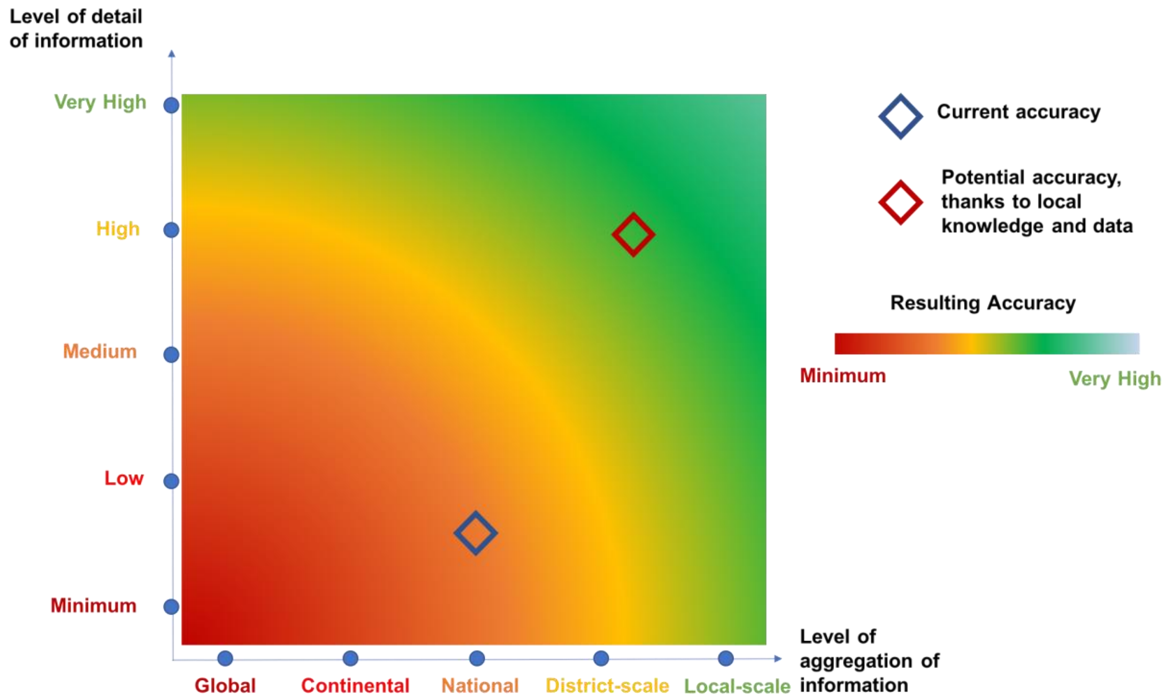

Figure 1: Plot showing the overall level of accuracy of the Risk Assessment, depending on (i) the level of detail of the information associated to the exposed elements (on the y-axis) and (ii) the level of spatial aggregation of the information (x-axis). The blue diamond represents the current level of accuracy, which we are able to reach with the available global datasets, while the red diamond represents the potential increased level of accuracy which can be reached thanks to local knowledge and data.

In the following sections, both standard global datasets and additional information from local stakeholders are discussed for each category of exposed element.

Built-up area

The built-up area exposure data are the main element for the economic evaluations and the construction of the AALs and PMLs curves.

Figure 2 reports a graphical sheet in which a series of data associated to the built-up area exposure dataset are indicated. Three main categories of data are identified: (a) data regarding the physical exposure (built-up area extent, construction typologies data, occupancy data) (b) the economic values and (c) the vulnerability. For each of these data, a series of different products can be used, which change in terms of resolution, both in terms of spatial scale and in terms of detail.

As an example, the built-up area extension can be represented using Built-Up raster layers obtained from Remote Sensing or can be described in a very precise and local way identifying the building footprints. Furthermore, the distribution of the main construction typologies (material, number of floors, elevation of the first floor etc.) can be aggregated at different scales, starting from the National scale arriving again to be reported at the building footprint scale.

These sheets, which are available also for the other categories of exposed elements, can be helpful to understand which kind of data are already available and which other data can be reasonably asked to the local stakeholders to improve the overall accuracy of their risk profile.

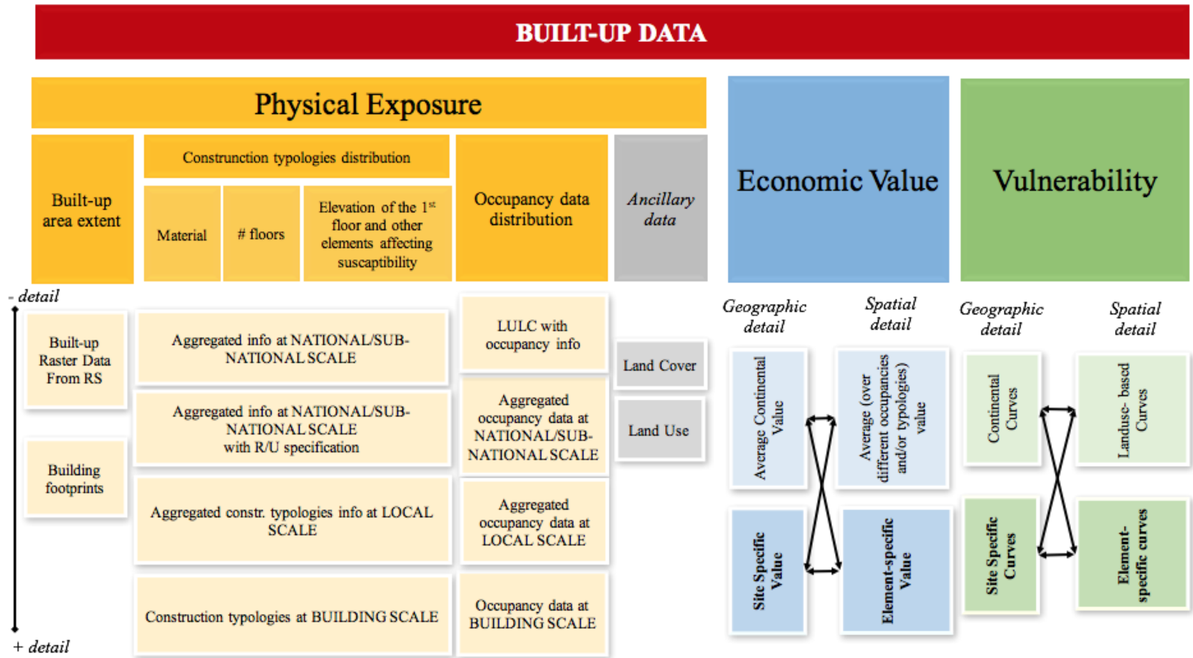

Figure 2: 'Built-up Area' graphical sheet in which are indicated a series of data associated to the built-up area exposure dataset.

Population

Population is by choice not considered from the economical point of view; in fact, in this study only the potential involvement of people in the considered scenarios was considered. To this end, it'd be appropriate to describe the population of a specific Country within the basin according to two different level of detail:

- the density, considered as the spatial distribution of population across the countries;
- the statistical distribution, according to the typical classifications useful in order to identify the most vulnerable portions of the populations (e.g. children, illiterates, etc.).

The potential levels of accuracy connected to these two characteristics of the population are depicted in Figure 3.

Referring to population density, the level of accuracy of the corresponding information arises when going from a raster representation (i.e. acquired from remote sensing data) of the population to a representation at (local) census level, or even at building level. Starting from the distribution of population density, that is mandatory to perform any impact analysis on population, one can refine the description adding a statistical distribution in classes linked to age, gender, employment, disabilities and other elements that could be linked to vulnerability; here again, the more this statistical distribution is linked to the local level, the more the level of accuracy increases.

Obviously, the level of accuracy of the data on population influences the level of analysis that can be potentially developed. In the context of the project, it was not possible to have a homogeneous statistical description of population across the basin; in fact, census information was usually available – depicting also such characteristics within the single countries – but it was not sufficiently homogeneous – in terms of reference time, or spatial representation, or indicators adopted – for providing a dataset to be used at basin level. For this reason, the choice was to perform a simple analysis, with the evaluation of people affected within the considered scenarios. The population distribution at spatial scale was thus elaborated starting from a high-resolution global dataset – namely WorldPop – integrated with census information for ensuring the consistency of the overall population quantity at the level of first subnational administrative subdivision. Whenever the population statistical distribution is added, it could be possible to evaluate also the typical social-oriented impact indicators (i.e. number of children in school age affected).

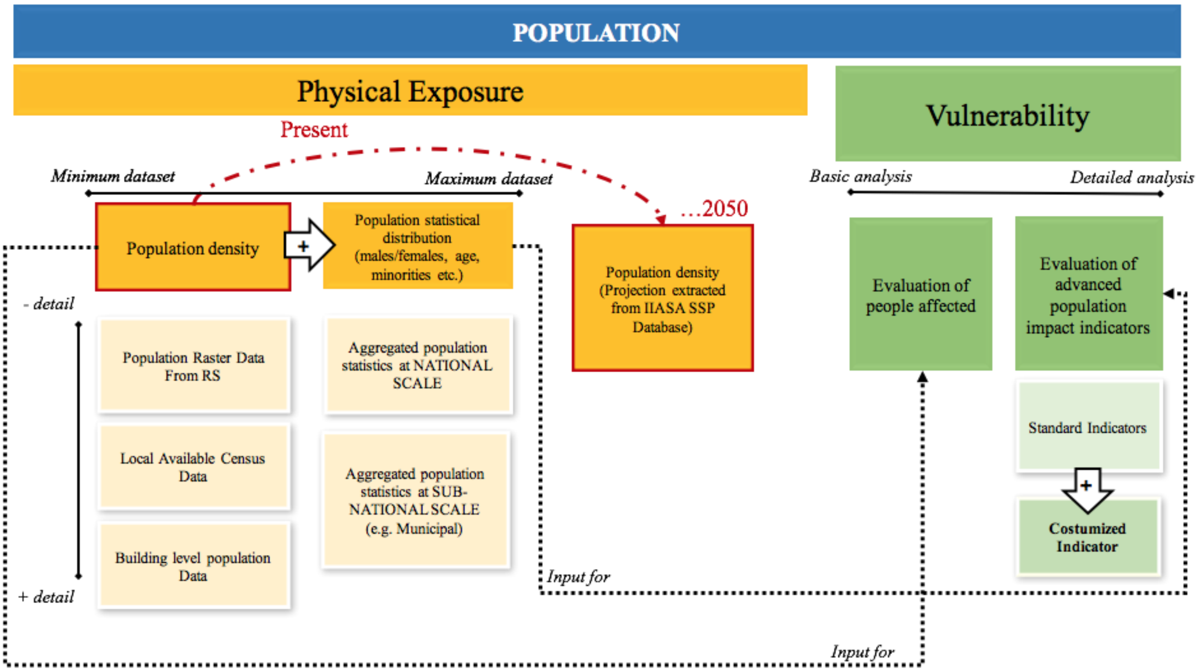

Figure 3: 'Population' graphical sheet in which are indicated a series of data associated to the population exposure dataset

Essential services and critical infrastructures

Essential services and critical infrastructures are a crucial part of any risk profile; in this context, we include in such category all those elements that critically contribute to the normal development of human activities. As such, according to geospatial data availability, it is proposed to treat as critical infrastructures the following elements:

- Transport networks
- Education facilities
- Health facilities

Different information levels required to characterize critical infrastructures in terms of physical exposure, economic value and vulnerability are illustrated in Figure 4, for point critical infrastructures, and in Figure 5 for linear critical infrastructures (i.e. transport networks).

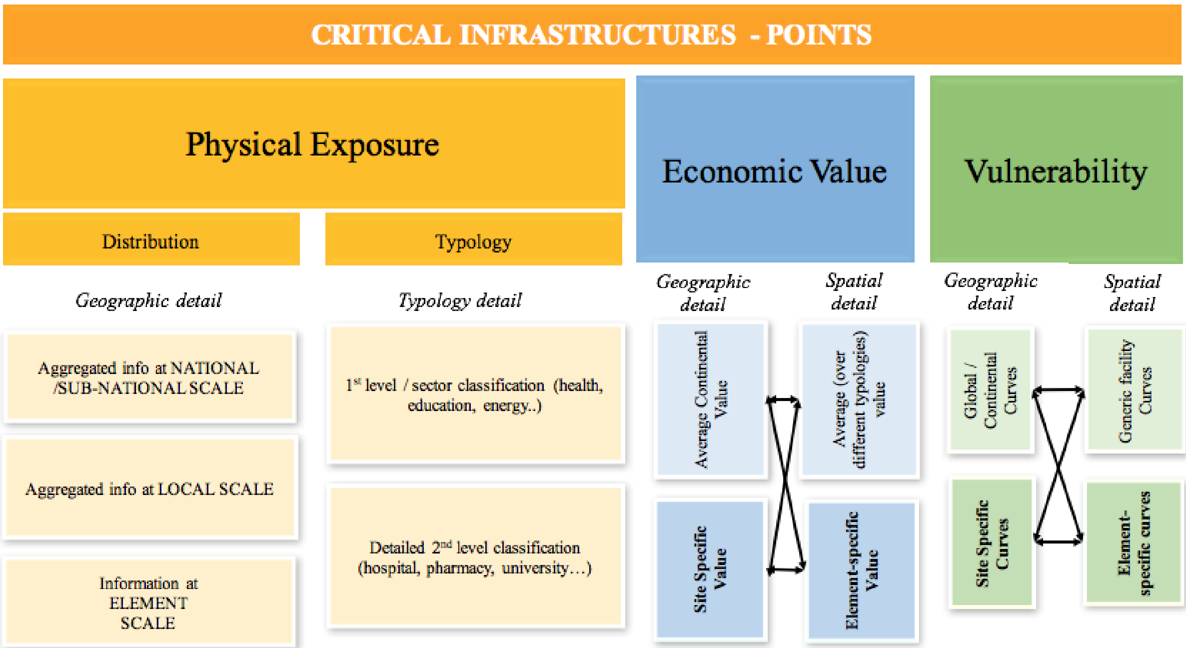

Figure 4: 'Critical Infrastructures - Points' graphical sheet in which are indicated a series of data associated to the point critical infrastructures exposure dataset.

For the point critical infrastructures (Figure 4), the physical description considers two different aspects:

- the distribution, i.e. the geolocation of the infrastructures, which can be aggregated at different scales (e.g. reporting the number of critical infrastructures inside a certain area) or can located exactly each single infrastructure in its real location
- the level of classification of the typologies, which can be very rough (e.g. distinguishing among 'health', and 'education') or quite detailed (e.g. 'health' can be further detailed in 'hospital', 'clinic', 'dispensary' etc.)

In the experience gained by CIMA in several years of activity on risk assessment, the representation of point critical elements is the one that most depends on the quality of information collected at local level. For this reason, the choice was to give relevance to data collected through the training process involving experts coming from countries within the basin, rather than looking for an homogeneous dataset at basin level; only some homogenization activity on the data structure was performed.

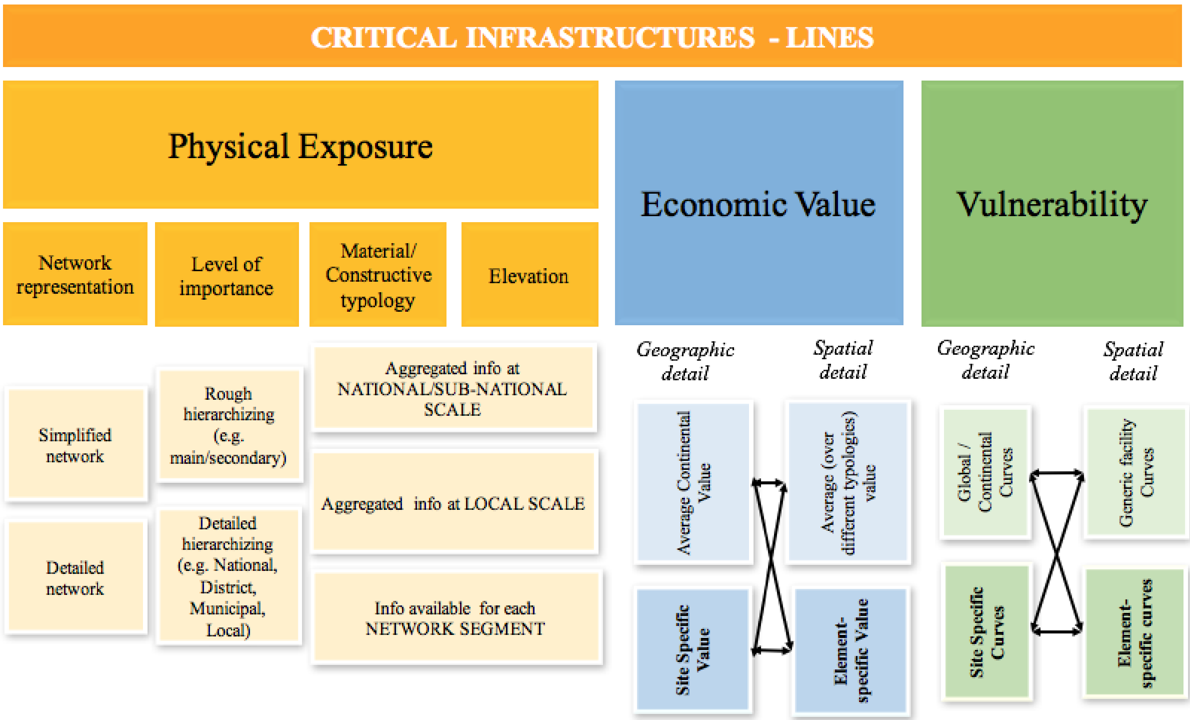

Figure 5: 'Critical Infrastructures - Lines' graphical sheet in which are indicated a series of data associated to the linear critical infrastructures' exposure dataset.

For the transport networks (Figure 5), the physical description considers the following aspects:

- the network representation, which can be obtained with different levels of detail
- the level of importance (i.e. the hierarchization) of the network elements, which can be very rough (e.g. distinguishing between 'main' and 'secondary' roads) or quite detailed (e.g. classifying the roads in 'national', 'district', 'municipal', 'local')
- information related to constructive features such as surface material (paved/unpaved) and elevation. This kind of information can be aggregated at different scales (e.g. reporting the percentage of paved/unpaved road at national or sub-national level) or can attributed specifically to each element of the network.

Here again, the choice within the project was to describe such an exposure category by the use of data made available at national level.

Agricultural and protected areas

When developing a probabilistic risk analysis with a strong focus on the economic consequences, the evaluation of the damages connected to agricultural production is usually based on the analysis of the potential losses in terms of production linked to specific flood events. To this end, exposure information coincides mostly with information on crop production (see Figure 6). The level of accuracy of this kind of data may depend on:

- the geographic detail used in order to represent the production (expressed preferably in tons/year) over the Country; the production value has to be expressed at least as a national value, but the corresponding level of accuracy can increase with a distribution at national/district level, or even at single producer level;
- the level of differentiation of the production among the different crop types; this differentiation can be pushed up to the level of the single crop type production.

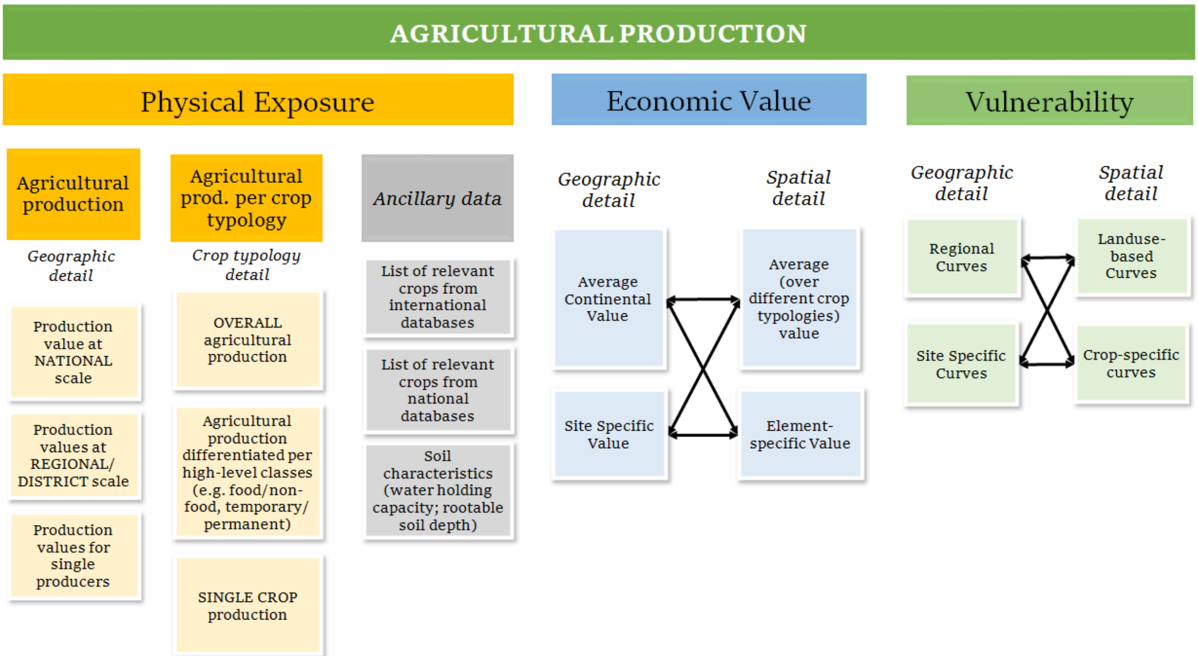

Figure 6: 'Agricultural Production' graphical sheet in which are indicated a series of data associated to the crops' exposure dataset

In the first phases of data collection conducted within the project it was not possible to depict a homogeneous framework in terms of agricultural production (and connected costs); for this reason, the choice was to widen the focus of the analysis to a more environmental- oriented description, including also areas dedicated to pastoralism, as well as protected areas. In doing this, the choice was to describe the consequences of floods in terms of area affected, whereas for droughts the analysis focused on potential losses in terms of yield and economic loss for maize crop (for which average costs were available), numbers of animals and hectares of protected areas in drought-affected areas.

Looking together to the future

The Volta Floods and Droughts Risk Profile (https://www.floodmanagement.info/floodmanagement/wp-content/uploads/2022/08/Volta_RiskProfile_Total_English.pdf) is not only the synthesis of insights gained during several months of collecting data and conducting risk modelling in the Volta basin, but also the result of having mobilized sixty national technicians for data collection and training and risk experts from the 6 riparian countries during national training process, consultative meetings and a strategic regional workshop. This opportunity, made possible through the implementation of the Volta Flood and Drought Management project, funded by the Adaptation Fund, once again revealed the importance of collaborative, fruitful relationships for knowledge sharing, horizontal learning and moving towards a common understanding of risks in the Volta basin region and each of the six riparian countries.

With this same approach, improvements and update of the risk assessment will be possible in the future.

The model developed for the risk assessment is of course a representation of the reality, the specific characteristics of which depends on:

- The objective of the overall study
- The available information.

Following these two lines, different improvements can be identified and some of them are here briefly introduced.

Focus on the local level

The original project had a regional (basin level) domain of interest. Whenever the risk profile should be the basis for decisions to be taken at national or local level, it is appropriate to adapt to the considered level all the modelling phases necessary for describing the risk components, namely hazard, exposure, and vulnerability, as well as the whole risk calculation.

Extension to different climate projections

In the original project, a selected number of climate projections was considered. The inclusion of different climate projections would allow the stakeholders for a more complete description of the potential consequences of floods and droughts; this action could be also necessary whenever new and update climate scenarios are made available by the scientific community. In this case, the whole "hydrological-hydraulic-flood scenarios" chain would need to be computed again, at least for the new climate scenarios.

Inclusion of mitigation and adaptation measures

Stakeholders can be interested in understanding how risk mitigation or adaptation measures could affect the overall flood and drought risks context. For doing this, it is necessary to identify on which specific component (hazard, exposure or vulnerability) each measure acts, and re-run the corresponding analysis.

Update of available information

The importance of local information was stressed along the lines of this document. It is thus evident that any improvement or update in the available information can help the overall quality of the results. Whenever new information is available, its potential contribution to the flood risk analysis should be evaluated; then, the corresponding risk components should be re-evaluated accordingly, as well as the overall risk computation. Hereafter a summary of potential contributions from local stakeholders for improvement, update and upgrade of useful information and datasets.

Variables	Agencies/partners which could bring support from the Six countries
Population	National Institutes for Statistics, research entities on demography
Built up information	National institutes for Statistics, National geographical institutes
Cropland	Agriculture ministries, agencies in charge of land use, National geographical institutes
Grazing land	Agriculture ministries, agencies in charge of land use and livelihoods, National geographical institutes
Road network	Infrastructure ministries, National institutes for Statistics, National geographical institutes
Health facilities	Health ministries, National institutes for Statistics, National geographical institutes
Education facilities	Education ministries, National institutes for Statistics, National geographical institutes
Protected areas	Environment ministries, IUCN, National geographical institutes

Identification of new indicators

The choice of the proper indicators to be proposed to the stakeholders it is fundamental for the acceptance of the results. Whenever new requirements arise, it should be evaluated if a proper answer can be given starting from the original problem structure, or if a different exposure characterization is required. For instance, for deriving the vulnerable groups affected by floods event can be sufficient to add a proper statistical description of the population in the exposure description; instead, if we want to derive the potential displacements induced by floods, a different association of population with essential services should be added (Ponserre and Rossi, 2022).

Conclusions

All these potential improvements would require the collaboration of different players with an approach based on collaboration, knowledge sharing and horizontal learning.

Local stakeholders could have a main role in the collection, update and upgrade of information regarding the different risk components. The local experts joining the training phase of the project on risk mapping could be involved in such a process, and they would be able to update and extend exposure and impact assessments with scenario-based approach, by considering new information especially in terms of hazard (new or upgraded hazard maps with higher resolution and related to several return periods) and stock (updated and more detailed data). They could also give important contributions to the evaluation and validation of consequences connected to single flood scenarios based on assessment data of occurred past events.

CIMA, or other scientific partner with relevant experience in the field could be considered as scientific expert supporting the calculations associated to the modelling of each risk component within the probabilistic risk assessment. Such a player could also join the efforts with the Volta Basin Authority (VBA), the World Meteorological Organization (WMO), and other regional stakeholders in the area, as the Global Water Partnership West Africa (GWP-WA) in the definition of the scopes of the work, the identification of the proper stakeholders to be involved, the selection of suitable indicators for describing the risk context, and the definition of proper dissemination activities.

Hereafter a summary of roles and responsibilities of different stakeholders for updating the existing hazard, exposure and impact GIS layers and maps after the VFDM project completion in 2024.

Trained technicians	Knowledge of methodology and tools for updating the GIS layers
National agencies	Make available the new or updated data and information
Regional agencies (VBA and GWP-WA)	Make available resources (human, financial, etc) for updating the risk maps
CIMA	As a technical partner can lead the update or improvement of the risk maps or profile jointly with the national agencies and technicians based on mutual agreement with the regional entities

Annex 1: List of focal points

A list of focal points is provided for the different stakeholders in each of the six riparian countries and at regional level, who will support and contribute in updating the risk maps after the project.

Country	*Agency/Entity*
Benin	*VBA NFS*
	Meteo agency
	Hydro agency
	Disaster Management agency
	...
	....
Burkina Faso	*VBA NFS*
	Meteo agency
	Hydro agency
	Disaster Management agency
	...
	....
Cote d'Ivoire	*VBA NFS*
	Meteo agency
	Hydro agency
	Disaster Management agency
	...
	....
Ghana	*VBA NFS*
	Meteo agency
	Hydro agency
	Disaster Management agency
	...
	....
Mali	*VBA NFS*
	Meteo agency
	Hydro agency
	Disaster Management agency
	....
	...
Togo	*VBA NFS*
	Meteo agency
	Hydro agency
	Disaster Management agency
	....
VBA	
GWP-WA	

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