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ETHIOPIA	Water and Land Resources Institute (WLRI)
FINLAND	Finnish Environment Institute (SIKE)
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ITALY	Italian Research Council (CNR)
KENYA	Kenya Agricultural & Livestock Research Organization (KALRO)
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THE NETHERLANDS	International Soil Reference Center (ISRIC)
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Abstract (for dissemination)	Water resource management is a sensitive topic in East African river basins, both for managing irrigation and ensuring food security. The management of water is closely connected to the sustainability of other natural resources, such as biodiversity, ecosystem functions, soil, energy, and livelihoods. Deforestation, overgrazing, soil and water degradation, and – on a socio-economic level – a reduction in agricultural productivity and agricultural system efficiency are some of the consequences of demographic pressures, unplanned rural development, and lack of alternative livelihood opportunities in many East-African areas. By using innovative research, modelling and capacity building approaches, WATDEV seeks to gain a deeper understanding of small to large-scale water and agricultural resource dynamics and management. In this Report on the current water, soil and crop management practices in the four countries involved in WATDEV, state-of-art of best management practices applied in the project areas are collected and analyzed by a survey based on Project Description Sheets and Practices Evaluation Sheets specifically developed as questionnaires.
Keywords	Best Management practices, inventory, survey

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Acronyms and Abbreviations

AICS	Italian Agency for Development Cooperation
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa, Uganda
ATM	Atmosphere
AU-EU	Africa-Europe
BMP	Best Management Practice
CIHEAM	Centre International de Hautes Etudes Agronomiques Mediterranéennes, Italy
CLT	Cultural
CNR-	Consiglio Nazionale delle Ricerche, Italy
CRP	Crop
DG DEVCO	The Commission's Directorate-General for International Cooperation and Development
ECO	Economic
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
GOV	Governance
HU	Heliopolis University, Egypt
ISRIC	International Soil Reference Center, The Netherland
KALRO	Kenya Agricultural & Livestock Research Organization, Kenya
POL	Political
R&I	Research and Innovation
SOL	Soil
STI	Science, Technology and Innovation
SYKE	Finnish Environment Institute, Finland
WAT	Water
WATDEV	Climate Smart WATer Management and Sustainable DEVelopment for Food and Agriculture in North and East Africa
WLRI	Water and Land Resources Institute, Ethiopia
WRC	Water Research Centre, Sudan

Executive Summary

Water resource management is a sensitive topic in East African river basins, both for managing irrigation and ensuring food security. The management of water is closely connected to the sustainability of other natural resources, such as biodiversity, ecosystem functions, soil, energy, and livelihoods.

Deforestation, overgrazing, soil and water degradation, and – on a socio-economic level – a reduction in agricultural productivity and agricultural system efficiency are some of the consequences of demographic pressures, unplanned rural development, and lack of alternative livelihood opportunities in many East-African areas.

By using innovative research, modelling and capacity building approaches, WATDEV seeks to gain a deeper understanding of small to large-scale water and agricultural resource dynamics and management.

In this Report on the current water, soil and crop management practices in the four countries involved in WATDEV, state-of-art of best management practices applied in the project areas are collected and analyzed by a survey based on Project Description Sheets and Practices Evaluation Sheets specifically developed as questionnaires.

1. Introduction

This deliverable includes the results of a survey aimed at collecting data on established best management practices (BMPs) from the areas involved in the project. This activity is part of a broad engagement and awareness-raising action that aims to close the gap between state-of-art of BMPs and the further steps of implementation and innovation actions.

The survey has been conducted through questionnaires that have been conceived for collecting data on the current available projects describing the application of BMPs in the four countries involved in WATDEV, i.e., Egypt, Ethiopia, Kenya, and Sudan.

The advantage of questionnaires as a research method is that they can gather large amounts of information based on a large sample size in a fast and inexpensive manner.

The aim was to collect qualitative and quantitative data at different scale level, comparable across diverse geographical area, as well as across different agricultural systems.

The survey aims at collecting information that is available in existing data sources, and that will be used in the subsequent step of the project, including the modelling processes. The survey focuses on how best management agricultural practices are applied, how they impact on ecosystems and natural resources, and how they can increase farmers and agriculture resilience to climate change.

The information gathered also relates to the used BMPs on the considered project areas, the social-economical drivers behind the adoption and the implementation of these practices, and the innovation potential and technological characteristics of the BMPs itself.

Main goal was to build a dataset from which management practices could be extracted, evaluated, and shared with local communities in the frame of WATDEV.

2. Overview (for the 4 Countries together)

2.1. Climate

Egypt is located in the north-eastern corner of Africa, and it is represented mostly by arid climatic zones according to Köppen–Geiger climate classification (https://climateknowledgeportal.worldbank.org/country/egypt).

Ethiopia harbours a diverse climate and landscape, ranging from equatorial rainforest with high rainfall and humidity to desert-like conditions.

Overall, Ethiopia is considered largely arid. However, a large variability of precipitation allowed to divide Ethiopia into three main climatic zones: the alpine vegetated cool zone, the temperate zones in areas between 1,500 and 2,500 meters above sea, and the hot zone, which encompasses both tropical and arid areas (https://climateknowledgeportal.worldbank.org/country/ethiopia).

Sudan possesses a Sahelian belt with the desert in the far north, and several fertile lands mainly distributed close to Nile River. According to Köppen–Geiger climate classification system, main classes in Sudan are represented by arid and semi-arid climate (https://climateknowledgeportal.worldbank.org/country/sudan).

Kenya covers a land area which includes varied formations of plains and, and hills, as well as low and high mountains. Approximately 85% of Kenya's land area is classified as a fragile arid and semi-arid ecosystem.

Highlands are relatively cool and agriculturally rich. Along with semi-arid climate classification, Kenya is reported to mostly harbor tropical savanna climate zones (https://climateknowledgeportal.worldbank.org/country/kenya).

2.2. Agricultural production

Cereals dominate Egyptian and Ethiopian crop production. Main crops cultivated in Egypt are corn, potato, banana, orange, grapes, tomato, and sugar beet; while in Ethiopia are mostly cultivated corn, barley, sweet potato, peas, avocado, and coffee (Ritchie et al., 2020).

Kenya agricultural production is based mainly on bean, banana, avocado, and tea. Lastly,

Sudan has the lowest agriculture production (Ritchie et al., 2020). Tomato is one of the most cultivated vegetable crops with onion (Ahmed and Mohammed, 1995) and sorghum (Ahmed, 2000).

2.3. Water resources

Egypt is one the countries that mainly face water scarcity, because of the limitation in groundwater, rainfall, and desalinated water.

The main source of water is represented by Lake Nasser that provide water to Nile River from which water is detract for human purposes. Water re-use or water alternative sources are still underdeveloped sectors. One of the major challenges that Egypt will face will be the construction of a dam in Ethiopia, that will significantly reduce Nile recharge (Abd Ellah, 2020).

More of 60% of **Sudan** area is placed in the Nile basin and it share water resources with Egypt, as Nile represent the major source of water. Groundwater exploitation or alternative water sources are still underdeveloped compartments, as for Egypt (Omer, 2008).

Ethiopia has a complex topography, diversified climate, and different types of water resources. The spatiotemporal variability of the water resources is characterized by multi-weather systems rainfall of the country. In general, Ethiopian water resources are more diversified as compared to Egypt and Sudan, thanks to the presence of different rivers. The country has 12 major basins, 12 large lakes, and differently sized water bodies whose water availability follows Ethiopian rainfall (Berhanu et al., 2014).

Kenya water resources are scarce and limited and the major source are Tana River and Lake Victoria Basin, which accounts for more than half of Kenya's freshwater. Several dams provide surface water, but water storage reduce water flow for downstream users. Groundwater is often contaminated and, for this reason, poorly exploited (USAID/Sustainable Water Partnership, 2021).

2.4. Management practices trend (traditional vs modernization)

In Africa, different international institutions are working together with the World Bank and the Food and Agricultural Organization (FAO) groups to develop agricultural systems that will enhance and boost food production at all levels, from global to local.

Subsequently, a shift to climate-smart agriculture (CSA) has been observed in several African countries, where most of these practices have been assessed and promoted, also in Ethiopia and Kenya (Makate et al., 2019; Maindi et al., 2020).

CSA also promotes the application of low-income agricultural systems such as conservation agriculture. However, in the four countries, modernization of agriculture is still at the beginning.

In Kenya, for example, most farmers still rely on traditional agricultural practices, and nearly 24% of the population is undernourished (Barasa et al, 2021). Consequently, sustainable agriculture concept including CSA is recognized to be not widely applied in Africa (Ogemah, 2017), and agricultural productivity still must be improved, especially in the current climate-changing scenario.

For example, while on average agriculture employs 65% of African labor force, it accounts for about 32% of gross domestic product, reflecting the relatively low productivity in the sector (Gitau and Mwangi, 2019).

3. Methodology

The survey has been conducted through the development and use of two questionnaires, customized to be filled by researchers from the WATDEV partner countries, by evaluating available projects in scientific literature and open-access databases.

A pre-screening on identified projects (Guidelines; Annex 1) putatively describing BMPs has been performed through the filling of a specific format (Project Description Sheet; Annex 2) aimed at assessing the methodology and data from BMP application in field in the screened projects.

The Project Description Sheet represented a summary, containing the main information regarding the project's location, the availability, sources, the scope of the project, and how and from whom the project was managed. Once filled, the Project Description Sheets and all eventually attached documents of each project were uploaded into the dedicated WATDEV cloud.

Once projects were described, a Practices Evaluation Sheet for each detected BMP was used as a format to assess the BMP feasibility encompassing different aspects in detail. Practices Evaluation Sheets were prepared as questionnaires consisting in 2 main open-ended questions related to info on evaluated projects and applied BMP(s) and 27 multiple-choice questions specifically focused on the effects on different sectors (water, soil, atmosphere, crop management), as well as on socio-economic aspects (Table 1).

Table *1* - Questionnaire of Practices Evaluation Sheet

No.	Question
1	Best Management Practice's name
2	Best Management Practice's short description
3	CLT01 – Was the practice already/previously applied in the area?
4	CLT02 – Is the practice accepted by the beneficiaries?
5	POL01 – Is the practice supported by the national/local subsidies/incentives system?
6	POL02 – Is the adopted practice in line with the national/local policy and legislation?
7	GOV01 – Was the practice adopted by means of a participatory process involving relevant actors at the local level?
8	GOV02 – Does the practice require an organizational framework?
9	ECO01 – Does the net return per worker a/o landowner increase because of the implementation of the practice?
10	ECO02 – Is access to microcredit for the implementation of the practice feasible by relevant users at the local level?
11	ECO03 – Does the practice answer to the market demand (e.g., crop diversification/selection)?
12	SOL01 – Does the practice ensure soil conservation from losses due to erosion and incidental or deliberate exposure to the elements (sun, wind, water, fire, animal/machinery traffic, others)?
13	SOL02 – Has the organic matter in the soil increased?
14	SOL03 – Does the practice avoid disruption of soil structure?
15	SOL04 – Is the water-holding capacity of soil increased?
16	WAT01 – Is the practice able to improve groundwater quality and/or quantity?
17	WAT02 – Has the practice improved surface water quality and/or quantity?
18	WAT03 - Has the practice reduced water logging and water salinization?
19	WAT04 – Has the practice increased the resistance of crops and/or farming systems to salinity?
20	WAT05 – Is the practice able to improve water use efficiency?
21	CRP01 - Has the practice improved crop productivity and/or reduced yield variability?

No.	Question
22	CRP02 – Is the practice able to contribute to food safety and/or security and better livelihood for the beneficiaries?
23	CRP03 – Does the practice foresee farmers are engaged – both individually and collectively – to assure the availability of high-quality and diverse planting materials and/or animal breeds?
24	CRP04 – Does the practice focus on genotypes that can be multiplied on-farm, and can be well integrated into the local agro-ecosystem?
25	CRP05 – Is the practice able to increase the resistance of crops and/or farming systems to pests?
26	ATM01 – Is the practice able to enhance soil carbon sequestration and reduce greenhouse gas (GHGs) emissions?
27	ATM02 – Is the practice able to prevent losses of methane and nitrous oxide?
28	ATM03 – Is the practice able to reduce losses of water by evaporation / evapotranspiration?
29	ATM04 – Is the practice able to increase the tolerance and/or resilience of crops and/or farming systems to climate variabilities?

Briefly, among the 27 multiple-choice questions, 2 were related to define if the considered BMP was applied and accepted by the local communities (CLT), 2 to policy and legislation on the BMP (POL), 2 to the possible presence of relevant actors and organizational framework (GOV), and 3 to economical background of the applied BMP (ECO).

Outcome effects of evaluated BMP were assessed by questions on impact on soil (4 questions), water resources (5 questions), crop management (5 questions), and atmosphere (4 questions).

The possible answers to the multi-choice section of the questionnaire were “YES”, “NO”, “Not applicable – N/A” and “DON’T KNOW”.

The questionnaire was filled in a dedicated online form available to WATDEV partners (https://www.research.net/r/BMP_Evaluation).

The whole survey of BMP collection was carried out from April 18th to August 31st, 2022.

Statistical assessment of the collected data was performed by a Chi-square Goodness of Fit Test, with significance level of $P < 0.05$.

4. Current state of management practices (by country and sector)

Results of Project Description Sheets and Practices Evaluation Sheets were analyzed during September 2022.

A total of 213 Practices Evaluation Sheets were collected, among which, 192 were validated following in silico evaluation.

Discharged sheets (21) included incomplete filled forms for which more than 50% of answers were missing.

The dataset of results from the 192 validated sheets is attached as Annex 3. Overall, most of the identified BMPs (62.5%) involved processes with relevant actors (e.g., extension agencies, NGOs, etc.) at local level and required an organizational framework (53.64%) (Figure 1).

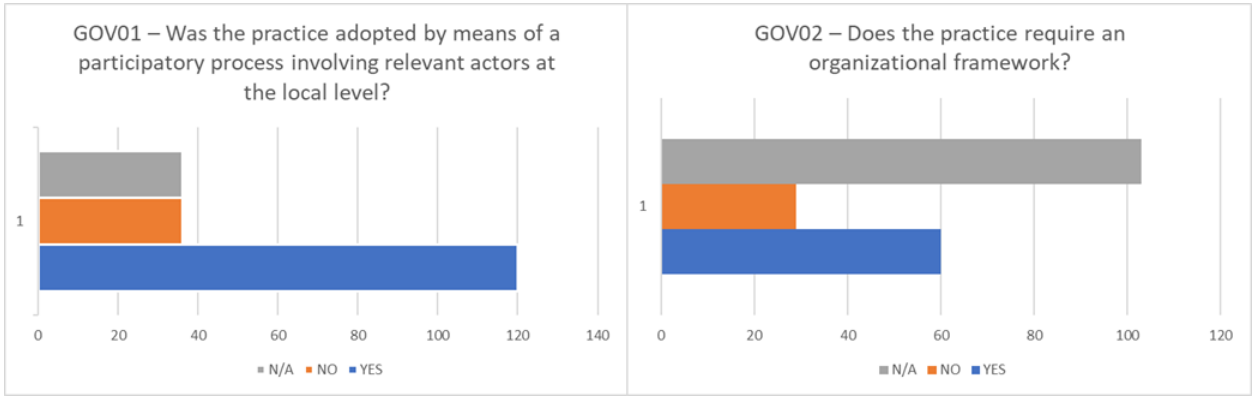

Figure 1 - Results of the survey related to the two GOV questions.

Answers related to POL questions showed that the 52% of the evaluated BMPs were supported by national/local authorities, and that 41.6% of these were in line with local/national legislation (Fig. 2).

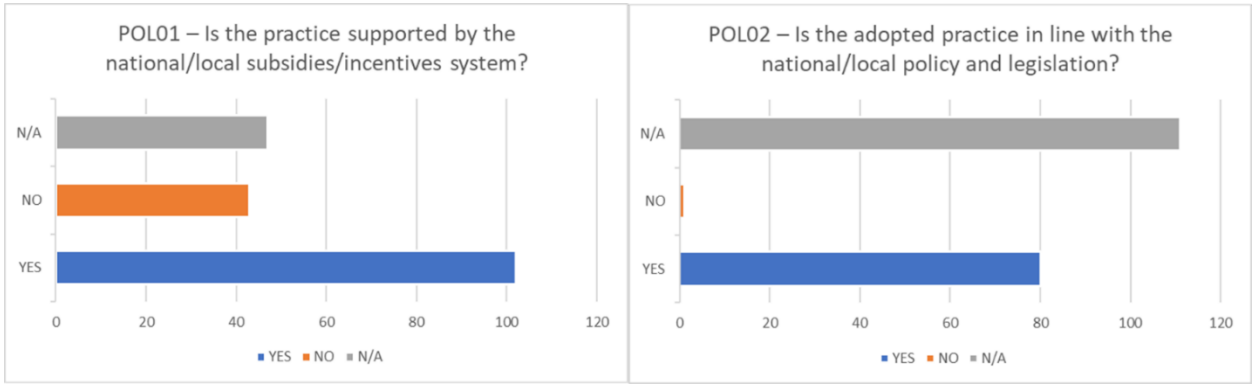

Figure 2 - Results of the survey related to the two POL questions.

Concerning economical questions, almost all (83.5%) BMPs lead to an increase in income for farmers and the 23.4% required access to microcredit (Fig. 3).

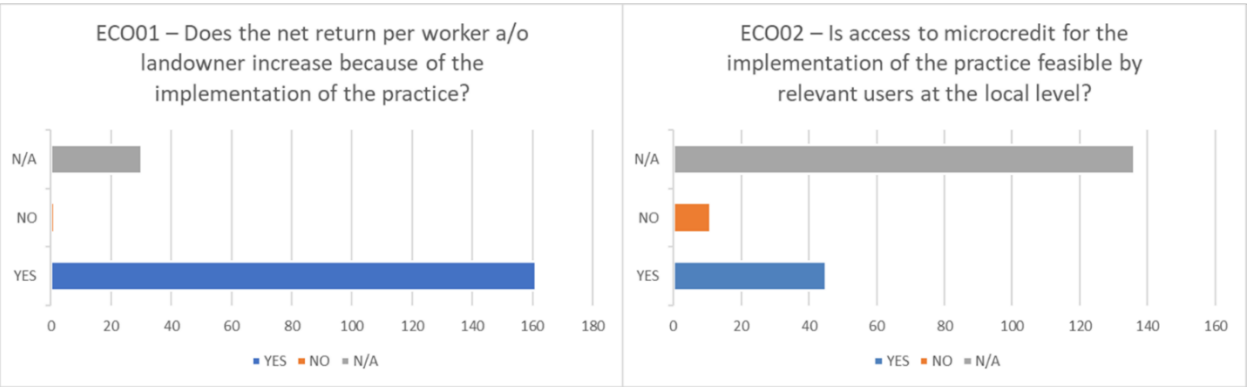

Figure 3 - Results of the survey related to ECO questions.

Overall, approximately 25% of Practice Evaluation Sheets were associated to areas outside of the countries involved in WATDEV. The remaining sheets were differentially distributed across the four considered WATDEV countries (chi-squared = 41.906, df = 4, p-value = 1.744e-08; Figure 4).

The lowest response proportion was observed for Egypt (about 7% of the total).

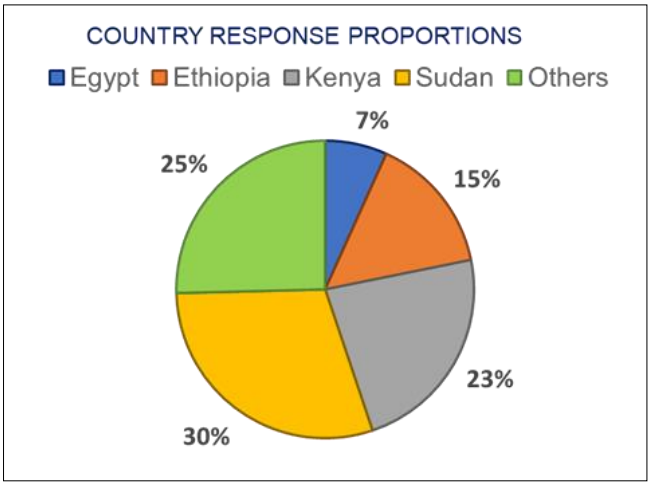

Figure 4 – Geographical distribution on evaluated projects in the Practice Evaluation Sheets**.**

Among the 192 validated sheets, the four considered sectors (water, soil, crop management, atmosphere) were differentially represented as percentages (Figure 5). Chi square test outcomes showed that the distribution of BMPs among sectors was significantly different (chi-squared = 105.3, df = 3, p-value < 2.2e-16).

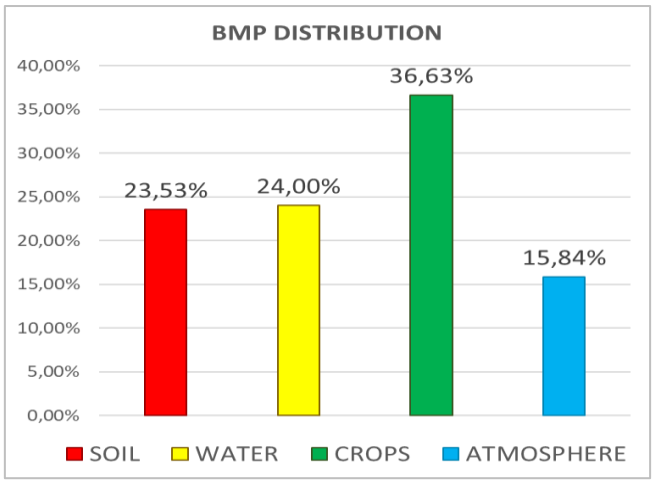

Figure 5 - BMPs distribution within the four considered sectors.

4.1. Egypt

For Egypt, a total of 8 Practice Evaluation Sheets were scored.

4.1.1. Water

Data collection about BMPs related to water (Fig. 6) showed that 50% of the BMPs are related to resistance to salinity improvement sub-sector.

Surface water improvement, groundwater improvement, logging/salinization reduction and water use efficiency sub-sector are equally represented (12.50% each).

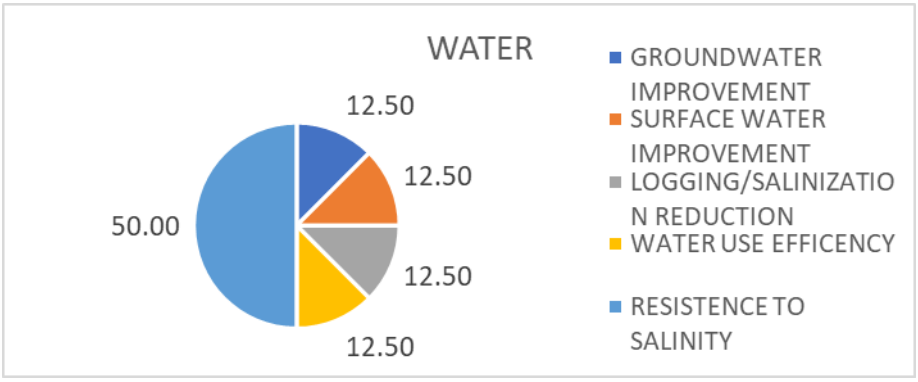

Figure 6 - Distribution in sub-sectors of BMPs related to water sector (Egypt). Percentages are showed outside the pie chart.

4.1.2. Soil

BMPs related to soil sector (Figure 7) are equally distributed in three sub-sectors, respectively soil conservation improvement, soil structure preservation and soil organic matter improvement (30.77%).

Less represented BMPs are related to enhance of soil water-holding ability (7.69%).

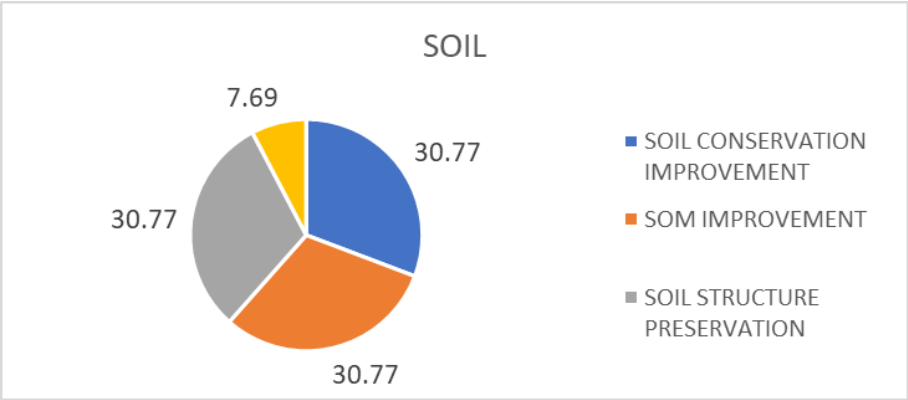

Figure 7 - Distribution in sub-sectors of BMPs related to soil sector (Egypt). Percentages are showed outside the pie chart.

4.1.3. Crop

BMPs related to crop sector (Figure 8) are mainly represented by BMPs that enhance crop productivity (44.44%), while BMPs related to farmer engagement, pest control and genotype selection sub-sectors use are less represented (11.11% each).

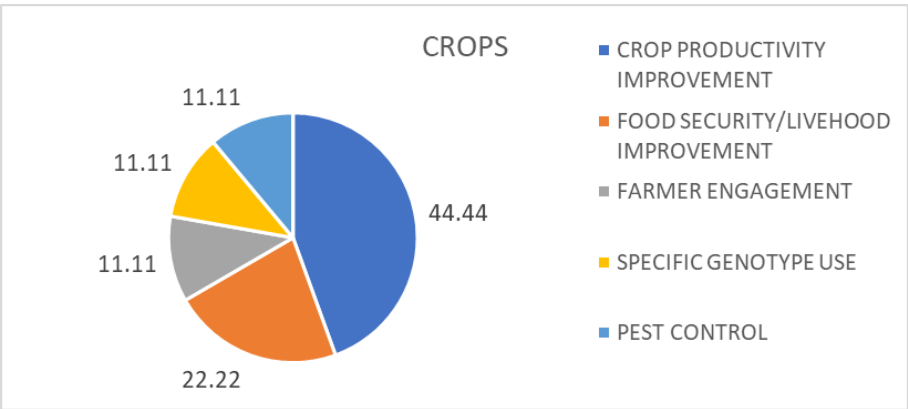

Figure 8 - Distribution in sub-sectors of BMPs related to crop sector (Egypt). Percentages are showed outside the pie chart.

4.1.4. Atmosphere

Concerning BMPs related to the effects on atmosphere sector (Figure 9), data collection showed two major sub-sectors representing BMPs impact on greenhouse gasses emission (33.33%) and improvement of resilience against climate variability (33.33%).

Evapotranspiration reduction by BMPs accounted for 25% of the total, whereas a limited number of scored BMPs related to methane/nitrous oxide reduction.

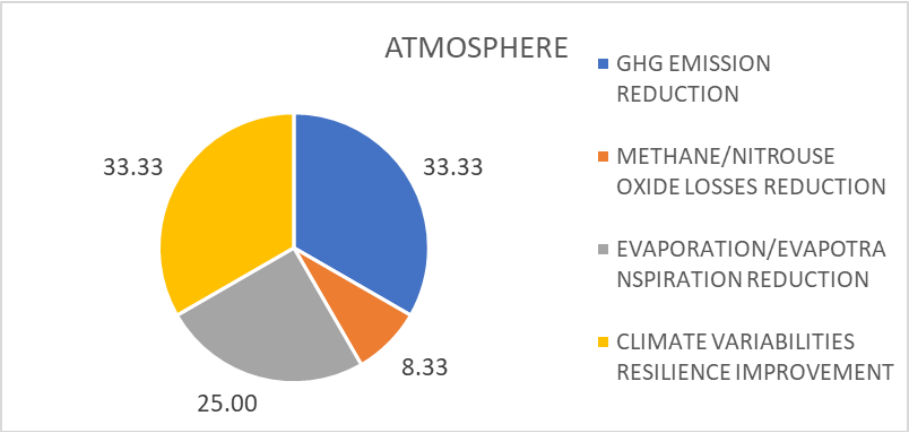

Figure 9 - Distribution in sub-sectors of BMPs related to atmosphere (Egypt). Percentages are showed outside the pie chart.

4.2. Sudan

For Sudan, a total of 54 Practice Evaluation Sheets were scored.

4.2.1. Water

The BMPs related to water in Sudan mostly impact on tolerance to salinity (46.97%; Figure 10). Surface water improvement and reduction of logging or salinization sub-sectors are equally represented (18.18% and 19.70%).

On the other hand, BMPs applied to improve water use efficiency and groundwater are less observed (6.06% and 9.09%).

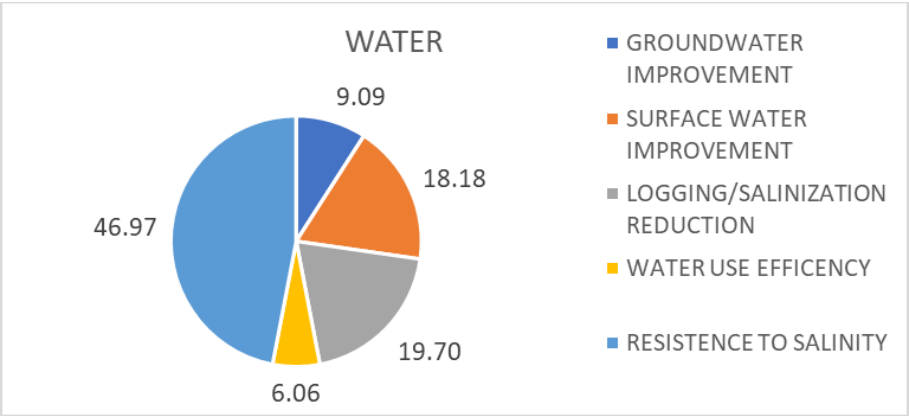

Figure 10 - Distribution in sub-sectors of BMPs related to water sector (Sudan). Percentages are showed outside the pie chart.

4.2.2. Soil

BMPs applied to improve soil compartment are represented for 31.25% by soil water-holding improvement and for 29.69% by improvement of soil conservation (Fig. 11). Soil organic matter increase, and structural preservation accounted for 23.44% and 15.63%, respectively (Figure 11).

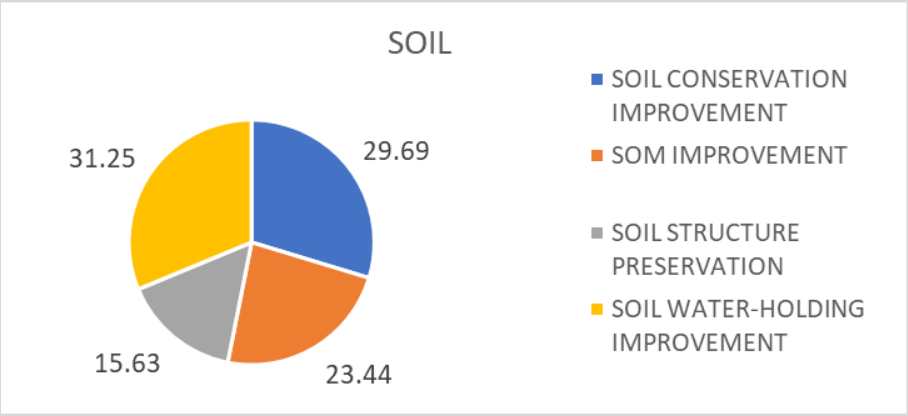

Figure 11 - Distribution in sub-sectors of BMPs related to soil sector (Sudan). Percentages are showed outside the pie chart.

4.2.3. Crop

BMPs applied in the crop management sector (Figure 12) account for 32.03% for improvement of food security/human livelihood and for 37.50% for the improvement of crop productivity.

Farmer engagement sector account for 14.84%, while a smaller number of BMPs are related to pest control and selection of specific genotypes (7.81% each).

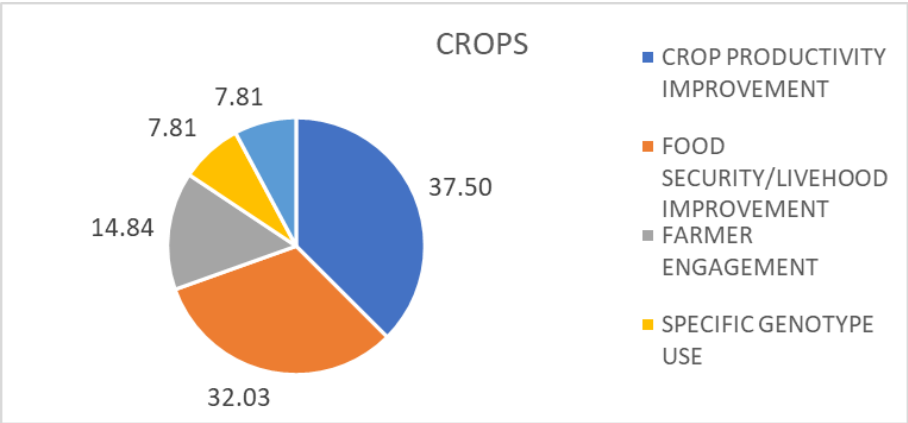

Figure 12 - Distribution in sub-sectors of BMPs related to crop sector (Sudan). Percentages are showed outside the pie chart.

4.2.4. Atmosphere

Most of the BMPs applied in atmosphere sector (Figure 13) attempted to reduce evaporation or evapotranspiration (43.86%).

BMPs that improved resilience against climate variabilities accounted for 26.32% and BMPs that were able to reduce greenhouse gasses emission accounted for 21.05%.

The least represented sub-sector is related to BMPs able to reduce methane/nitrous oxide losses (8.77%).

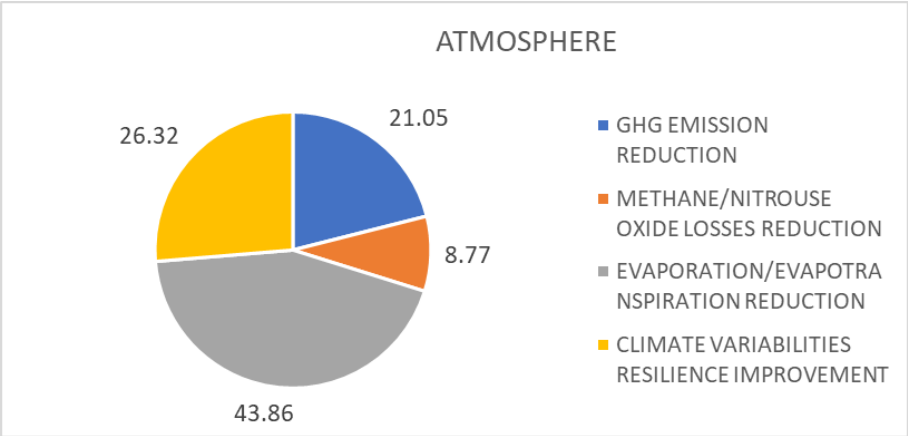

Figure 13 - Distribution in sub-sectors of BMPs related to atmosphere (Sudan). Percentages are showed outside the pie chart**.**

4.3. Ethiopia

For Ethiopia, a total of 29 Practice Evaluation Sheets were scored.

4.3.1. Water

Concerning water sector, BMPs related to the improvement of resistance to salinity accounted for 39.47%, followed by BMPs related to improvement of surface water (34.21%).

BMPs able to reduce logging/salinization or able to improve groundwater are less observed (10.53% and 15.79%).

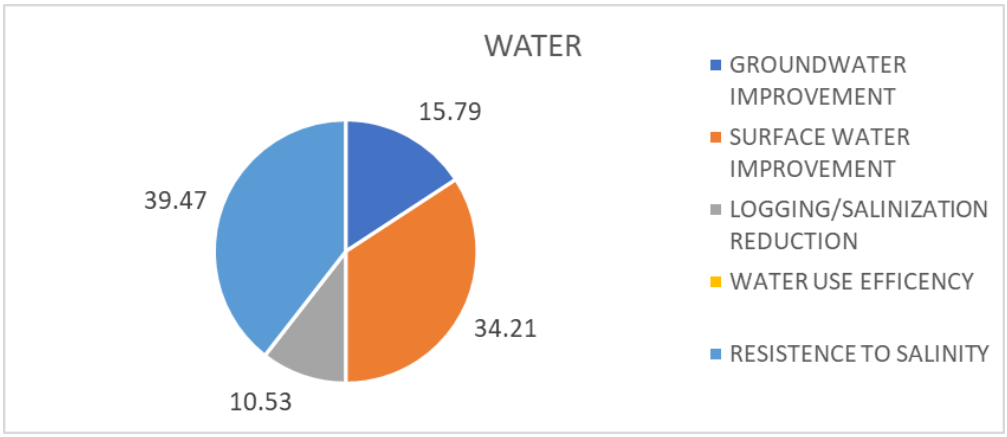

Figure 14 - Distribution in sub-sectors of BMPs related to water sector (Ethiopia). Percentages are showed outside the pie chart**.**

4.3.2. Soil

Soil sector (Figure 15) is represented by BMPs able to improve soil conservation (35.19%), followed by BMPs able to improve soil organic matter (25.93%), BMPs able to improve soil water-holding ability (20.37%) and, lastly, BMPs able to improve soil structure preservation (18.52%).

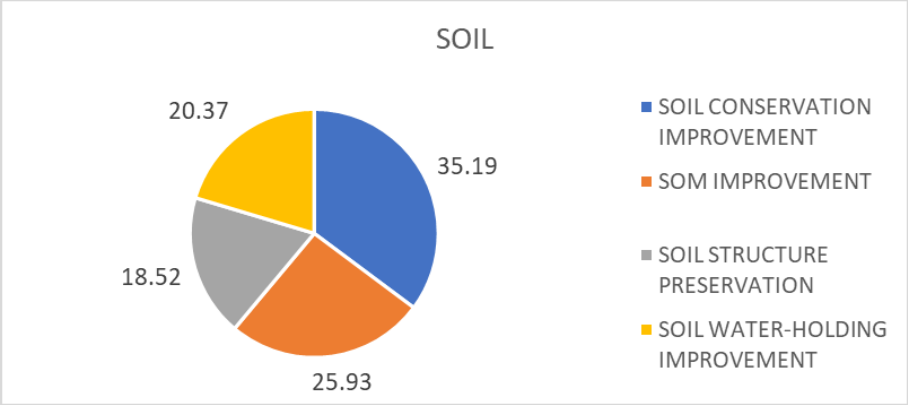

Figure 15 - Distribution in sub-sectors of BMPs related to soil sector (Ethiopia). Percentages are showed outside the pie chart.

4.3.3. Crop

BMPs applied to crop (Figure 16) mostly improve crop productivity (40.98%).

Less observed BMPs were linked to improvement of food security/human livelihood (27.87%), on farmer engagement (19.67%), on selection of specific genotypes (6.56%) and on control pests (4.92%).

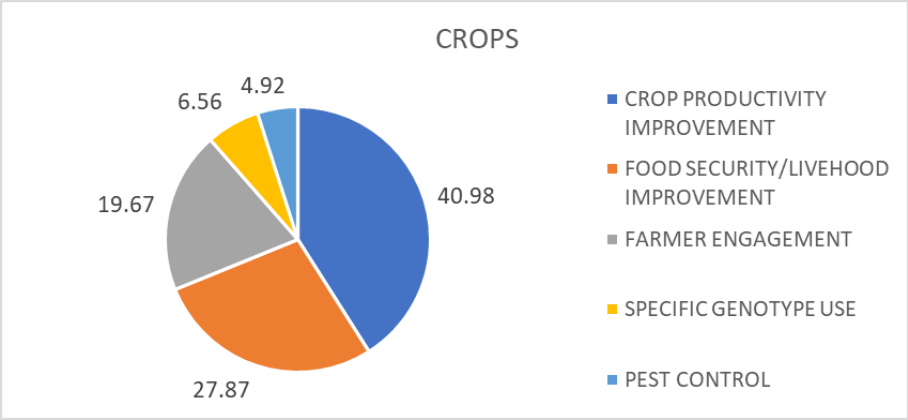

Figure 16 - Distribution in sub-sectors of BMPs related to crop sector (Ethiopia). Percentages are showed outside the pie chart.

4.3.4. Atmosphere

Atmosphere sector (Figure 17) is half composed by BMPs related to the improvement of resilience against climate variabilities sub-sector (50%), while the other half is composed by BMPs related to the reduction of greenhouse gasses emission (25%) and the reduction of evaporation/evapotranspiration

(25%). Percentages are showed outside the pie chart.

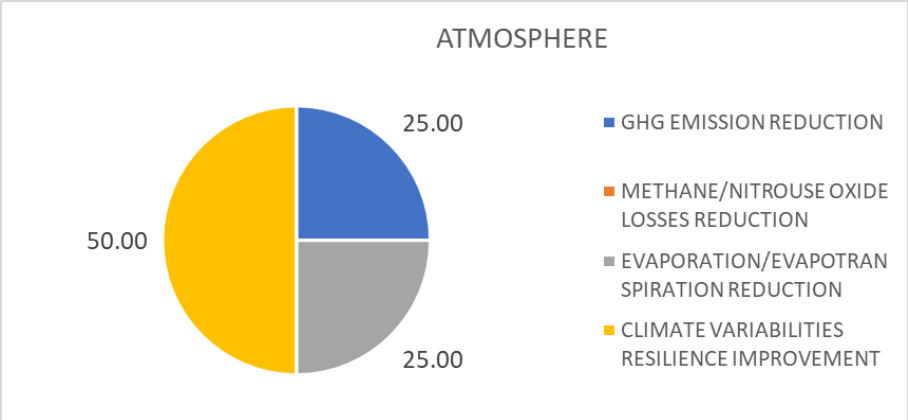

Figure 17 - Distribution in sub-sectors of BMPs related to atmosphere (Ethiopia).

4.4. Kenya

For Kenya, a total of 45 Practice Evaluation Sheets were scored.

4.4.1. Water

BMPs related to water sector are applied mostly to improve resistance to salinity (40.63%).

Less observed are BMPs related to groundwater improvement (16.67%), surface water improvement (16.67%), logging/salinization reduction (14.58%) and water use efficiency (11.46%) (Figure 18).

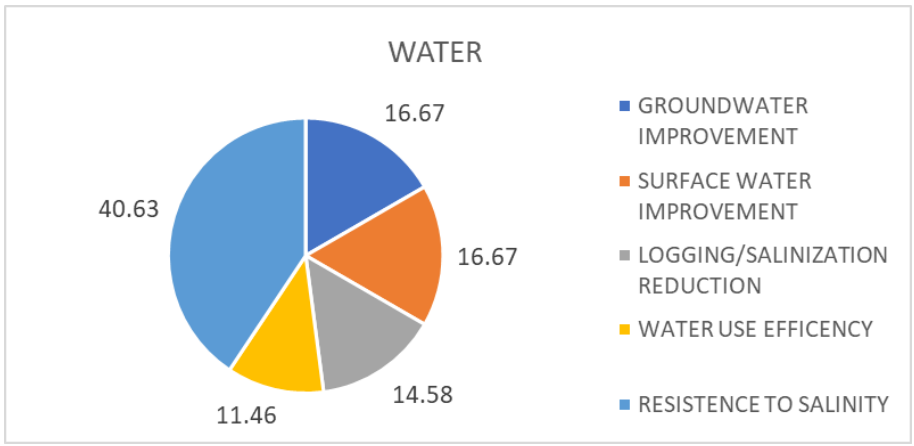

Figure 18 - Distribution in sub-sectors of BMPs related to water sector (Kenya). Percentages are showed outside the pie chart.

4.4.2. Soil

Soil sector (Fig. 19) is represented mainly by BMPs applied to improve soil water-holding ability (40.32%).

BMPs related to the improvement of soil conservation account for 32.26%, followed by BMPs related to soil organic matter improvement (20.97%) and soil structure preservation (6.45%).

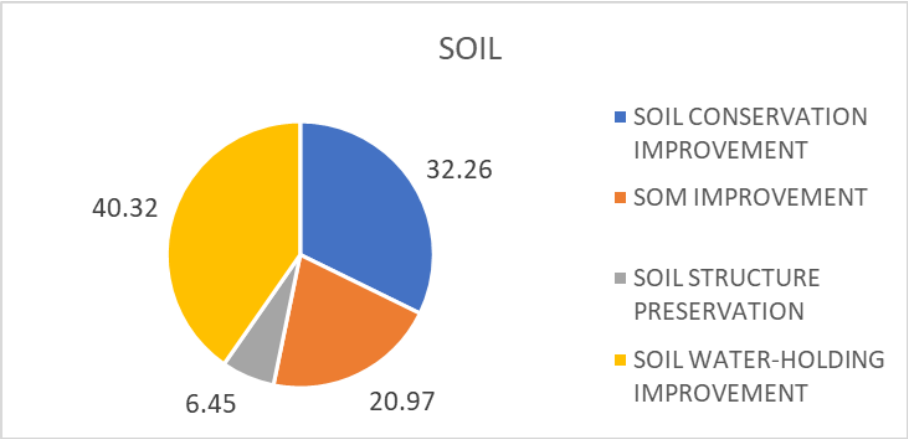

Figure 19 - Distribution in sub-sectors of BMPs related to soil sector (Kenya). Percentages are showed outside the pie chart.

4.4.3. Crop

BMPs related to crop sector (Figure 20) are applied mainly to improve crop productivity (40.18%), followed by BMPs able to improve food security/human live hood (33.04%), BMPs related to selection of specific genotypes (11.61%), BMPs able to control pests (8.04%) and, lastly BMPs based on farmer engagement (7.14%).

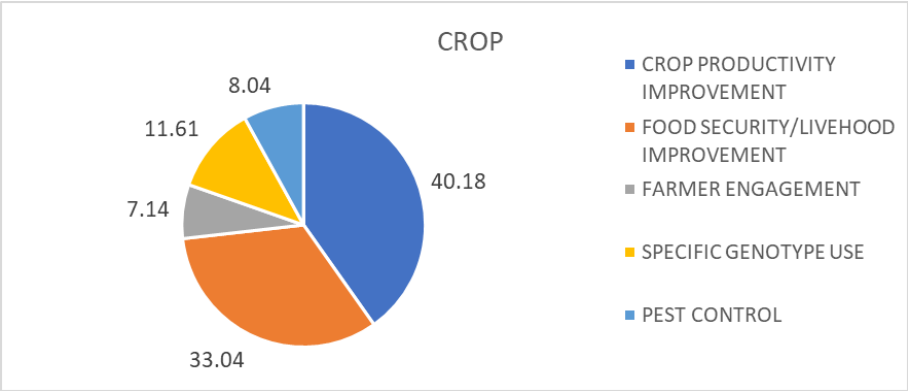

Figure 20 - Distribution in sub-sectors of BMPs related to crop (Kenya). Percentages are showed outside the pie chart.

4.4.4. Atmosphere

More than a half of BMPs related to atmosphere sector (Fig. 21) are applied to improve resilience against climate variabilities (58.33%).

Less observed are BMPs related to the reduction of greenhouse emission (20%), the reduction of methane/nitrous oxide losses (10%) and the reduction of evaporation / evapotranspiration (11.67%).

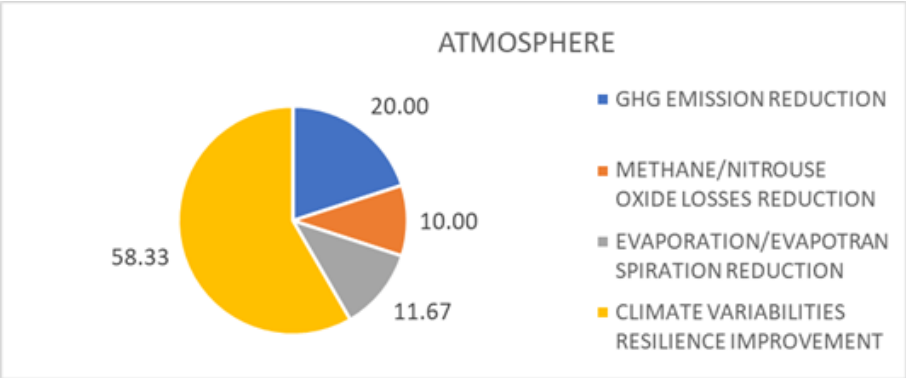

Figure 21 - Distribution in sub-sectors of BMPs related to atmosphere (Kenya). Percentages are showed outside the pie chart.

5. Conclusions

In conclusion, the survey conducted in the frame of WATDEV step of BMP evaluation allowed to catch a glimpse on the established BMPs in the four WATDEV African countries.

The survey highlights that BMPs are generally embedded in agricultural systems in the African countries, and that most of them have an impact on water and soil resources.

However, BMPs related to crop management are still at the top of the practices applied in the areas, suggesting a great interest on crop yield and productivity and less focus on ecological implications, especially on atmosphere.

It should be also noted that, compared to other three considered countries, data from Egypt are limited and additional information are needed.

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