Evaluate Damage and Loss of Egyptian Natural Land Cover due to Climate Temperature: Accounting Approach

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Abstract

The World Meteorological Organization report (2021) indicated that the most climatic factor that affects the achievement of the sustainable development goals (SDGs) is temperature. Therefore, this study aims to introduce a new accounting mechanism to estimate the potential damages and losses (D&Ls) in the value of Egypt's natural land cover due to the incremental temperature using the accounting appraisal value approach. The comparative analysis of two climate scenarios indicates a potential D&Ls value due to temperature impacts under the protection scenario. It reveals that D&Ls would exist even with mitigation and adaptation efforts but with considerable cost savings as an opportunity cost to be invested in further wealth value creation or retention by land cover, which may reach US$482.3 billion by 2100. We recommend that estimated adaptation costs and protection programs should comprehensively cover all natural land cover types (besides agricultural land) and the related biodiversity to be able to maintain natural capital wealth and reduce the probability of D&Ls.

Keywords: Accounting for climate change, Loss and damage accounting, Land cover change, Valuation for wealth accounts, Natural capital biodiversity, Climate resilience.

تقدير الأضرار والخسائر في الغطاء الأرضي الطبيعي لجمهورية مصر العربية بسبب حرارة المناخ: مدخل محاسبي

ملخص

أشار تقرير المنظمة العالمية للأرصاد الجوية (2021) إلى أن درجة الحرارة هي أكثر العوامل المناخية التي تؤثر على تحقيق أهداف التنمية المستدامة. لذلك، تهدف هذه الدراسة إلى تقديم منهجية/آلية محاسبية جديدة لتقدير الأضرار والخسائر المحتملة **(D&Ls)** في قيمة الغطاء الأرضي الطبيعي في مصر بسبب درجة الحرارة المتزايدة باستخدام مدخل تَقْدير القيمة محاسبيًا. يشير التحليل المقارن لسيناريوهين مناخيين إلى استمرار وجود قيمة للأضرار والخسائر المحتملة بسبب تأثيرات درجة الحرارة في ظل سيناريو الحماية. ويكشف التحليل عن استمرار الأضرار والخسائر حتى مع جهود التخفيف والتكيف ولكن مع وجود توفير(خفض) كبير في تكلفة/قيمة الأضرار والخسائر يمكن استخدامها كتكلفة فرصة بديلة للاستثمار في خلق المزيد من قيمة الثروة أوالاحتفاظ بها من خلال الغطاء الأرضي، والتي قد تصل إلى 482.3 مليار دولار أمريكي بحلول عام 2100**.** توصي الدراسة بأن تغطي التكاليف المقدرة لبرامج التكيف والحماية بشكل شامل جميع أنواع الغطاء الأرضي الطبيعي (إلى جانب الأراضي الزراعية) والتنوع البيولوجي لها حتى نتمكن من الحفاظ على ثروة رأس المال الطبيعي وتقليل احتمالية الأضرار والخسائر.

الكلمات الدالة: المحاسبة عن تغير المناخ، محاسبة الخسائر والأضرار، تغير الغطاء الأرضي، تقييم حسابات الثروة، التنوع البيولوجي لرأس المال الطبيعي، المرونة المناخية.

1 Introduction

Nowadays, there is an incremental awareness about the impacts of climate change, which is posing deadly threats to humankind, especially the most vulnerable that are the least well-off. The negative impacts of climate disasters usually affect the lowest contributors to greenhouse gas (GHG) emissions, and these countries also have the lowest coping capacity (Evans, 2021). Although China was the top contributor to global CO_2 emissions in 2016, emitting 10.5GtCO2 (7.38 per capita), Canada, Australia, and the US emitted the highest CO_2 per capita among developed countries, emitting 18.58, 17.1, and 15.52, respectively (Worldometer, 2022).

Paris Agreement is possibly the last chance for countries to avoid the more catastrophic effects associated with the climate system. With incremental climate hazards, countries are expected to be motivated to make significant cuts in emissions to enhance CO_2 removal from the atmosphere, including natural solutions such as re-growing forests (Ogle and Kurz, 2021). However, in recent times, the damage and loss (D&L) caused by a warming climate (such as the recent floods in Germany and New York and the wildfires in the UK, France, and Algeria) is likely to grow in the future and would affect all countries, both poor and rich. Therefore, it needs to be considered seriously. D&L is a broad concept that can be addressed in a variety of ways. (Huq and Soderberg, 2021).

From the climate change perspective, D&L have been described by the UN Framework Convention on Climate Change (UNFCCC) (2022) as the effects of both sudden-onset occurrences such as cyclones and slow-onset processes such as the rise in sea level. Although human and natural systems, such as livelihoods and biodiversity, suffer D&Ls, research and policy usually focus on human impacts. In the context of the human system, distinctions have been made between economic and non-economic losses based on the availability to be traded in markets (UNFCCC, 2013).

Although the D&L concepts were initially framed in the context of insurance and risk transfer, which involves liability and compensation value, political discussions on climate have dramatically changed the meaning of the concepts. After two decades of political debate on international climate, D&L were recognized by the UNFCCC in 2013 at the 19th Conference of the Parties (COP) by establishing the Warsaw International Mechanism (WIM) on D&L, which was linked to the impacts of climate change. The WIM enriched the implications of scientific research and policy. Thus, in 2015, at the COP21 in Paris Agreement (Article 8), WIM facilitated the international climate policy movements from debate to action to provide a permanent legal basis for the D&L Mechanism, (Mechler, 2020), although the US, Australia, and Canada supported the removal of any liability or compensation reference to D&L

from the negotiation text (Vanhala and Hestbaek, 2016).

In 2021, at the COP26 in Glasgow, the Glasgow Facility for Financing D&L was proposed to support the creation and development of adaptation and mitigation policies and programs in over 50 developing vulnerable countries (Huq, 2022**)**. Thus, in June 2022, at the first session of the Glasgow Dialog on D&L finance in Bonn, developed and developing countries continued their disputes about the new and additional finance facility for D&L and who should pay for the tougher targets, including climate D&L and emission cuts. However, no official agreement has been settled with a new enthusiastic attitude from developed countries to involve wealthy emerging economies and the private sector to fund climate finance (Carbon Brief, 2022).

From an accounting perspective, the damage concept is broader than the loss concept because damage includes both tangible losses and value reduction after a climate change event. It involves financial and non-financial forms of damages, whereas loss is estimated in monetary form by directly incurred costs and/or lost profits from climate change (Gissing and Blong, 2004; Morrissey and Oliver-Smith, 2013; Oksana, Bruneckiene and Simanaviciene, 2014). The impacts of climate change can alter decision-making substantially and change priorities, especially when considering the monetary value of policies, projects, and programs. Therefore, the effects of the appraisal approach for climate change are usually adopted to do climate risk assessment by identifying and comparing the potential elements of the costs and benefits of the baseline scenario with the alternative scenario(s) (DEFRA, 2020; O'Mahony, 2021). However, when comparing alternative scenarios, the adaptation and mitigation investment costs can be ignored. This is either because the magnitudes of D&L that may threaten lives continuity or investment needs cannot be determined because of the absence of prior estimates for potential climate impacts over a specific capital or investigated area.

Recently, climate D&L has become a top current item on the COP27 agenda in Egypt 2022 and the political agenda of countries receiving incremental calls to conduct a regular D&L gap evaluation report similar to the adaptation and emissions gap reports (CSO Equity Review, 2019). In Egypt, three National Communication reports have been prepared for UNFCCC (1990, 2010, and 2016), and one needs assessment has been conducted by EEAA (2010b). However, no integrated estimate for the expected quantitative and financial D&L for natural land cover assets or ecosystem diversity damages has been prepared.

This study contributes to the current movements toward achieving integrated estimates of D&L of natural land cover caused by the temperature climate in Egypt. The objective of this study is to estimate the expected value deterioration of the Egyptian natural capital of land cover up to 2100 under two climate change scenarios—business-as-usual (BAU) high emission scenario and after protective actions (APA) low emission scenario. To do so, this study adopts the accounting framework for temperature climate using the direct and indirect D&L approach to investigate the expected impacts on land cover change. Using two scenarios, the appraisal value[1] approach is adopted to predict the changes in the value of natural capital in Egypt up to 2100. The Egyptian land cover data and values are extracted from the international datasets of the FAO and World Bank, as well as international and national reports, published books, and journals. This study is limited to estimating D&Ls of natural land

[1] The appraisal value is the value of an asset based on a fair professional analysis process to evaluate the asset at a given point in time weighted by changes in climate factor.

cover[2] due to temperature and is not extended to measure the impact of land use change caused by people's behavior, population, urbanization, technology, productivity, trade, and consumer demand. It is also not extended to measure the direct or indirect impact of D&L on the human system.

This study finds a number of surprising results that are expected to significantly contribute to forming climate policies and programs in Egypt regard the actual value of natural capital D&Ls that Egypt exposure to carry due to incremental continues global GHG emissions compared with limited estimated adaptation costs that needs to be funded to achieve climate resilience. Furthermore, as Egypt's natural capital would keep suffering from

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[2] Land cover is the direct quantifications of number, size, volume, and observation to develop physical environmental accounting models, such as climatic and hydrological accounting models, whereas land use is the description of socio-economic activities of people on that surface, which is more relevant for environmental and human planning and policy purposes such as agriculture activities (Coffey, 2013; Fisher et al., 2005). As this study mainly focuses on natural land cover, farmlands/agriculture lands are considered produced vegetation land covers for comparative reasons, which are measured by the number of hectares. Additionally, the difference between two climate scenarios expectations—BAU and APA—is indirectly considering the future shift in anthropogenic factors.

incremental heat levels in the future, especially agriculture and bare land, it is essential to study this topic. Forest land would suffer from dramatic D&Ls over the next decades due to incremental heat with declining rainfall. Thus, even with mitigation and adaptation efforts, there would be D&Ls. These findings confirm the recent report of IPCC, support existing political debates, and justify the need for D&L finance.

The next section of this paper presents the literature review, highlighting the diverse D&L valuation approaches that have been adopted. Then, using the D&L approach, an accounting framework based on the impacts of direct and indirect climate change on natural land cover is introduced. Two climate scenarios—BAU and APA[3]—have been proposed to evaluate the D&L of the natural land cover value in Egypt. Finally, using the appraisal value approach, a comparative analysis is conducted. The discussion of the results follows, and conclusions are presented.

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[3] APA scenario is a low emission scenario that has been officially predicted by Egyptian Environmental Affairs Agency (EEAA, 2016) after taking protective actions and implementing a diverse range of adaptation and mitigation programs (EEAA, 2010b; 2018) in highly emitted sectors; mainly agriculture, coastal zone protection, energy and water resources and irrigation sector.

2 Literature review

At the UNFCCC level, the D&L concept has different interpretations among the parties. For example, Norway considers it as the residual risk when adaptation and mitigation are not met or are insufficient due to socioeconomic and/or technological barriers (soft limits). Although the Gambia follows the same meaning, it has adopted infeasible adaptation and mitigation actions to avoid risks (hard limits) (Lopez, et al., 2019; Mechler, et al., 2020). Comparably, Ghana and Bolivia are considering D&L as the adverse additional impacts of climate when no further possible adaptation is available, which may pose extra challenges in addressing and identifying it (Lopez, et al., 2019). However, at the country level, internationally agreed commitments to climate actions are assumed to be translated into climate strategies and policies, such as the Egyptian National Climate Change Strategy 2050 (Ministry of Environment, 2022) and the Australian National Climate Resilience and Adaptation Strategy (DAWE, 2021). The Egyptian strategy focuses on the alleviation and adaptation of the effects of climate change on the poor, economic growth and most vulnerable areas, whereas the Australian strategy seeks to achieve effective adaptation and enhance resilience through collaboration to drive actions, enable investments, and improve climate services and information over time. Bouyé et al. (2020) conducted a broad literature review and investigated climate policies to analyze the social impact of internationally agreed commitments of climate actions. They indicated that in addition to the decision-making engagement ability of diverse groups, especially in an inequality context, climate policies with an equity-focused approach usually care about costs and benefits distribution among social groups. The impact assessment of climate change and climate actions using the equity approach involves addressing distribution across society by considering the most vulnerable, disadvantaged, and least well-off groups with greater support and protection rather than developing gains and preventing socially adverse effects in the form of D&L.

D&L are often used as interchangeable terms. However, the terms are not identical and differ based on the circumstances and conditions of use. In a disaster context, losses are counts or the monetary value of physical assets, such as the number of injuries, fatalities, replacement value, and market value. Damage is a wider term, involving quantifiable or non-quantifiable measures and can be translated into monetary terms such as the cost of repairs, which can be included in the loss category (Oksana, Bruneckiene and Simanaviciene, 2014). The National Research Council (1999, p 35) recognized damages as indirect losses caused by natural disasters or their consequences, such as physical destruction, which are usually not measured as direct losses, whereas losses are the direct monetized value of physical destruction and its repaired costs. Additionally, damage may include indirect losses or value reduction, such as changes in future production, income, and employment and/or changes in these flows outside the damaged area.

Commonly, in economic law terms, the key difference is in the economic value and lawful matter. Therefore, any reduction in a property's economic value due to illegal activities is considered a loss, whereas any loss of property valuables protected by law is considered damage, regardless of the economic value (Oksana et al., 2014). From economic accounting perspective, Gissing and Blong (2004) defined loss as actual damage, including the direct damage caused by a specific natural event and directly estimated damages such as residential damage, whereas potential damage is the expected sustained losses when no action is taken for loss reduction such as commercial damage. Further, Oksana, Bruneckiene, and Simanaviciene (2014) indicated that direct disaster losses refer to directly quantifiable losses, such as the damage to natural resources, infrastructure, and buildings and the number of people killed. Indirect disaster losses (damages) include declines in revenue or output and the impact on the wellbeing of people, which generally emerge from disruptions to the flow of services and goods as a result of a disaster. Morrissey and Oliver-Smith (2013) defined D&Ls as somethings which are not accounted for within the accounting procedures by multiplying the value of damaged or lost by the number of it and/or which have no trade market. The financial perspective of climate change focuses mainly on cost–benefit analyses and the cost-efficiency of various measurements to avoid D&L, as well as the dealing cost with unavoidable D&L (Geest and Warner, 2015; O'Mahony, 2021). Furthermore, Gissing and Blong (2004) estimated the direct business losses and commercial damages caused by one of the flooding events in New South Wales Australia. They differentiated between two types of costs of tangible damages that resulted from direct contact with floodwaters—actual and potential damages. Actual damage includes the direct damage caused by a specific flood event and is estimated directly, whereas potential damage includes the sustainable damaged value when no action is taken to reduce loss. The results indicated large variability and inaccuracy in estimating commercial damages. Therefore, this study focuses on accounting concept of D&L where climate change may involve both financial and non-financial impacts. Loss is the direct tangible quantifiable impacts multiplied by asset value, while, damage is the indirect impacts on natural assets.

The sustainable development context usually focuses on interventions that enhance climate resilience in the long-term (Geest and Warner, 2015). Various classifications of the impacts of climate change using the term D&L have been introduced. Some studies consider D&L as inevitable climate impacts on human and natural systems (UNEP, 2016a; Dorkenoo, et al., 2022), whereas others described D&L as the adverse effects of climate that cannot be managed or avoided through adaptation and mitigation efforts (Geest and Warner, 2015; UNEP, 2016b). However, many studies are linking D&L to the values established in sustainable development goals (SDGs) (IPCC, 2022; Warner, 2018). Recently, McGrath and Hynes (2020) estimated the link between sustainable development and natural capital stocks from the perspective of depletion accounting using Green Gross National Savings approach. They considered explicit relationships between the values of natural wealth and environmental damages and sustainability indicators. They indicated the importance of developing ecological economic hybrid indicators; such as genuine savings, in the future to measure the sustainability and depletion of natural capital stocks. However, they emphasized that, in practice, using accounting prices for natural assets valuation may be not feasible and using physical terms may be needed especially to identify and measure the stocks of critical natural capital. Further, Boda et al. (2021) investigated the relationships between SDGs and D&L from the perspective of climate change using a systematic literature review approach. They considered explicit and implicit relationships, reaching four main classification groups that highlight theoretical linkages with sustainable development. They highlighted the absence of any explicit measurement of the impacts of climate change on natural and human development capabilities in D&L research.

As illustrated in Figure 1, human and natural systems have highly sophisticated interconnectivity, and these interactions are directly and indirectly affected by climate change (see UNEP, 2016a for more details). The human system includes the population; gross domestic product; tourism; food security (crops and livestock numbers); length of roads; the number of houses, properties, infrastructure; ancestral land; and social welfare (Liu et al., 2018; UNEP, 2016a). On the other hand, the natural system includes stocks (assets) of vegetation cover, such as forestland, grassland, wetlands, shrub land, and farmlands/agriculture land, as well as non-vegetation cover, such as bare land, water bodies, wildlife species, ocean, and glacier (Qu et al., 2020; Baskent, 2020). Further, ecosystem services cover food and fresh water supplies, biodiversity, soil formation, fuel storage, coral habitat, climate regulation, and disease regulation, as well as cultural services, including recreation (Baskent, 2020; UNEP, 2016a). Both the natural system and ecosystem services are considered natural capital that contributes to human wellbeing (Baskent, 2020).

A considerable range of literature has focused on the human system and how it is affected by climate change (Gissing and Blong, 2004; Oksana et al., 2014), whereas the natural system is usually treated as the physical environment that serves as the main provider of input resources for the human system and how it may be impacted by anthropogenic factors under different climate conditions (Huang, 2016; Liu et al., 2018). Recent studies have distinguished between the impacts of climate and

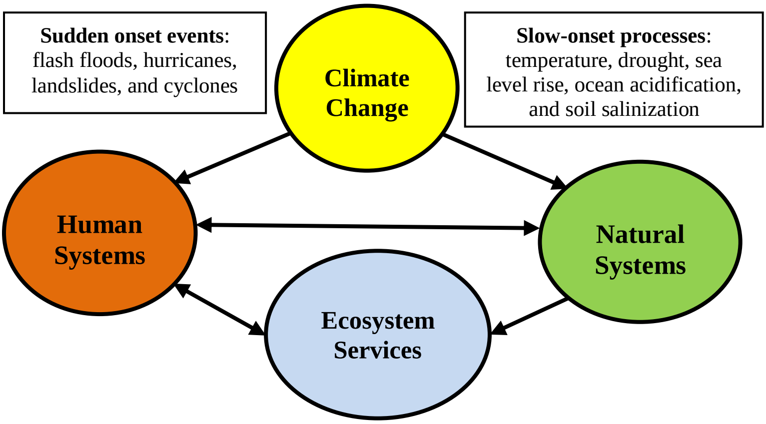

Fig. 1: Relationship among climate change and basic three systems. (Arrows indicate the impacts direction)
Source: Author modified from UNEP, 2016a.

human (land use) on vegetation changes (natural land cover) and the importance of quantifying them separately (Qu et al., 2020; Pan et al., 2017) to measure their impacts and how they should be quantified. Therefore, this study focuses on changes in natural land cover due to climate impact—the temperature factor—to quantify the separate impact of climate change on the natural capital of land cover.

The recent IPCC WG2 report (IPCC, 2022) emphasized the importance of natural vegetation cover in improving climate resilience. In Egypt, Koriesh and Abo-Soud (2020) indicated that species of trees that grow faster are more capable of absorbing and sequestering carbon, and some types can reduce methane concentration in the atmosphere. However, it has been found that some types of vegetation, mammals, and butterfly species in Egyptian protected areas are expected to significantly decrease or disappear due to climate change (Leach et al., 2013), whereas the natural non-vegetation cover, such as Lake Burullus[4], is expected to be negatively impacted by a significant increase in water temperature and salinity level by 2100 due to the combined effects of climate air temperature and sea level rise (Shalby et al., 2020).

Studies that have measured the effect of climate temperature, precipitation, and other climate drivers on changes in the natural land cover in the Egyptian context are relatively rare. Most studies on the Egyptian climate focused on the impact of sea level rise on Nile Delta agriculture activities and the north coastline (Abou-Mahmoud, 2021; Elshinnawy, 2012; Zhao et al., 2020). Other studies used geographic information systems (GIS) and satellite images to detect the historical changes in the Nile Delta land cover types (e.g., cropland, water bodies,

[4] Lake Burullus is an Egyptian lagoon at north coast line which is classified as valuable economic source for fish yield and fishermen livelihood in Egypt, as well as, tourism and agriculture. Further, it provides wide range of environmental benefits as a habitat for migratory birds, bird hunting, and recreation.

fish/wetland, and bare land) due to anthropogenic activities (Elagouz, et al., 2020) or to predict the impact of human urban expansions on diverse land cover types (Maged & Wang, 2020) with total negligence for the effects of climate factors and without clear consideration of the difference between the concepts of land change, i.e., land cover and land use (Coffey, 2013; Fisher et al., 2005).

Recently, a limited number of studies about Egypt have measured Nile Delta land use and land cover changes together without a clear quantified separation between both types of changes or between the main drivers using GIS and remote sensing methodology. For example, Kaky and Gilbert (2017) predicted the future impacts of climate change on medicinal plants distributions in Egypt, whereas Hereher (2017) investigated Nile Delta land changes over 15 years using a time series analysis of satellite datasets and found that the total loss in vegetation cover due to anthropogenic activities and incremental temperatures in the land surface is 62%. However, as far as we know, none of the previous studies have accounted for the expected value changes in Egyptian natural land cover assets over time. Thus, this paper introduces further insight into the literature by using an accounting approach, as presented in Section 3.2.

3 Accounting Framework for Climate Change impacts using the D&L Approach

3.1 Adopted Climate Change Accounting Approaches and Tools

In the UK, the appraisal approach has been adopted for climate change accounting (DEFRA, 2020). The approach considers weather variability and extremes and climate change effects on capital assets, either manufactured capital or natural capital. Manufactured assets include schools, housing health centers, and other important facilities, whereas natural assets include freshwater or marine, woodland, soils, wetland ecosystems, and coastal habitats.

Furthermore, HM Treasury (2020) introduced the social costs and benefits method as an assessment and valuation approach to appraise the range of environmental effects on the natural capital stocks of ecosystems. The harmful environmental effects include air pollution, GHGs, waste, and noise, whereas the natural capital effects include both living and non-living assets, such as forests, rivers, fisheries, biodiversity, minerals, and land. Additionally, the approach can evaluate the cumulative effects of multiple decisions on natural capital stocks and social welfare.

In France, Pichancourt, Manso, Ningre, and Fortin (2018) investigated the possible application of a software platform as a carbon accounting tool to detect GHG emissions life-cycle in the wood industry. The results revealed that the suggested accounting tool can provide information for managers and policymakers to achieve reductions in GHG emissions based on the production approach rather than other IPCC accounting approaches, such as stock-change, simple decay, and atmospheric flow (IPCC, 2006), or life-cycle carbon footprint (Finkbeiner and König, 2013). Using online software, the New Zealand Treasury (2020) adopted the cost and benefits analysis (CBA) guidance based on a "whole of life costs" approach to describe climate change values and social impact values over "estimated periods" and up to 2070.

In the Romanian context, Zgavarogea et al. (2021) estimated the GHG emissions/removals from the land use, land use change, and forestry (LULUCF) sector. The accounting approach to climate change (IPCC, 2019) guidelines for estimating GHG emissions was adopted for good practice. The results revealed a positive removal trend of 0.9% per year for total CO_2 absorption and 11.7% per year for methane absorption due to good practice and decreased settlement in wetlands. LULUCF and agriculture, forestry, and other land use (AFOLU) are categories of activities defined by IPCC in the context of emissions accounting. The LULUCF is part of the AFOLU category, which comprises emissions related to forest and other land use (FAO, 2022).

The Norwegian guidance adopted CBA to capture all relevant environmental and non-environmental effects of rail projects over 75 years (Norwegian Ministry of Finance, 2012). However, measuring the effects over longer timeframes, including the distant future, are subject to considerable uncertainty. Therefore, the guidance in Norway considered splitting the analysis into two periods—the "analysis period" and "residual period." The residual period intends to capture the long-term effects based on costs and benefits evolution during the analysis period. Further, scenario and sensitivity analyses are used when there is considerable uncertainty of the impacts.

In summary, environmental impacts are often accrued over the long-term. Therefore, time horizon analysis for environmental costs and benefits is much preferable for evaluating welfare gains or losses from an investment. Therefore, a historical analysis of the Egyptian climate factors is conducted in Section 4. Then, appraisal value analysis is conducted for climate D&Ls of natural capital to compare the potential changes in the value elements of the costs and benefits of the baseline scenario with the alternative scenario.

3.2 D&L approach

In the literature, there are two main approaches to assessing D&L for decision-making—the scientific approach and policy planning approach. The scientific approach is based on quantitative assessments, using scenarios for climate and socioeconomic impacts. This approach provides more information for the decision process to (1) identify the risks and raise awareness (Lopez et al., 2019), (2) minimize climate risk and manage climate D&L (Lopez et al., 2011), (3) estimate attributable climate D&L caused by anthropogenic or natural factors (Frame et al., 2017; Herring et al. 2014; Hulme et al., 2011), and (4) design and manage D&L costs and compensation instruments (Lopez et al., 2019; Linnerooth-Bayer et al., 2010). The policy approach is based on a planning process that investigates the pathways of adaptation/ mitigation and risk management based on a specific climate scenario. It is more flexible to allow adjustments and combine unpredictable changes and events, as well as unforeseen societal and technological developments over time (Bhave et al. 2016; Lopez et al. 2011).

Based on the underscored concept, D&Ls are unavoidable negative impacts that affect the natural environment, societies, and people temporarily or permanently (Dorkenoo et al.2022). Moreover, apart from the impact of non-climatic (human) drivers on natural land covers, it is important to separately quantify the impacts of climatic drivers (Qu et al., 2020; Pan et al., 2017). However, most climate studies in Egypt focused on the impact of sea level rise on the coastline and agriculture sector in the Nile Delta (Abou-Mahmoud, 2021; Elshinnawy, 2012). Recently, using GISs and remote sensing methodology, a limited number of Egyptian studies have measured Nile Delta land use and land cover changes together without a clear quantified separation between both types of changes or between the main drivers (Elagouz et al., 2020; Maged &Wang, 2020). For the first time, a scientific quantitative accounting approach has been adopted in this study, and two scenarios are used as the bases to account for D&L expected value changes in Egyptian land cover due to climate impact, mainly temperature, up to 2100.

Hence, this study aims to contribute to advancing D&L research by providing an integrative framing of Egyptian land cover diversity D&Ls. In this study, for accounting purposes, the damage concept is broader than the loss concept because damage includes tangible losses and value reduction after a climate change event. It involves financial and non-financial forms of damages, whereas loss is estimated in monetary form by directly incurred costs and/or indirect lost profits from climate change. Figure 2 illustrates the accounting framework for the D&L approach for diverse land covers. In the figure, direct and real losses that led to costs and/or lost profits due to climate factors are considered losses, whereas indirect value reduction and tangible loss that involved lost profits are long-term consequences.

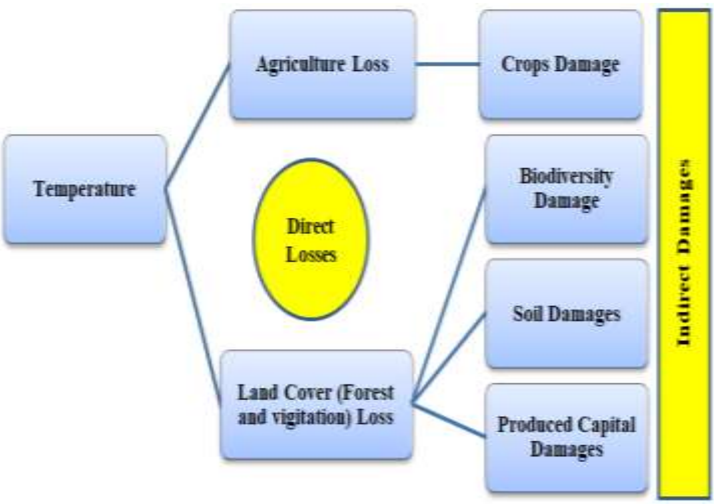

Fig. 2: Accounting framework for temperature climate factor using D&L approach. Source: Author.

3.3 Accounting mechanism for D&L

The relationships between the long climate historical records of temperature, precipitation, and

GHG emissions from 1960 to 2020 are investigated. Then, a historical trend of annual change in natural land cover and agricultural land cover is regressed and analyzed against climate factors using records from 1992 to 2018 to achieve robust estimates for D&L predictions (Lopez et al., 2019). The historical data are collected from the FAO database and CAPMAS from 1992 to 2019 reports. Regression analysis coefficients are used to estimate the impact of climate factors on land covers, either natural or produced. Human factors are excluded from the analysis because of the following reasons: (1) to focus mainly on the contribution of climate factors to changes in all land cover types investigated and (2) anthropogenic factors are indirectly considered under expectations of two climate scenarios—BAU and APA. In addition, the higher the number of driving variables (climatic and anthropogenic), the lower the actual impacts of these climatic variables because some human factors are known as dominant, and climate factors commonly have slow accumulated long-term impacts (Egidi et al., 2021; Hereher, 2017; Lopez et al., 2019).

The accounting framework for climate temperature is established based on the direct and indirect D&L approach using two climate scenarios to predict changes in land cover assets up to 2100. To evaluate the D&L rates under two climate scenarios—BAU and APA—the expected changes in ten types of natural land covers and five types of agricultural land covers are estimated using a climate predicted model based on the future predicted variance in temperature and precipitation levels (temperature is more dominant). By adopting the appraisal value approach, the expected changes in Egypt's natural capital values due to D&L are calculated using the recent World Bank wealth value accounts for land covers. Finally, the comparative cost and feasibility of the D&Ls of the two climate scenarios are illustrated as an opportunity cost for adaptation and mitigation programs. Therefore, the described accounting approach for Egyptian natural capital D&Ls evaluation can be applied and generalized to other climate factors, ecological, ecosystem services, and human capital systems. It is an accounting reference framework for the integrated assessment of climate impacts.

4 Results of comparative scenarios for implementation in Egypt

Egypt's total CO_2 emissions reached 199.87MtCO2 in 2019 (CAPMAS, 2021) with 2.32 CO_2 per capita (Worldometer, 2022). The energy sector is the major source of CO_2 emissions (83.22MtCO2) in Egypt, followed by the transportation (38.20 MtCO2) and industrial (30.80 MtCO2) sectors

(CAPMAS, 2021). However, in 2019, Egypt was classified as a highly vulnerable country to climate change impacts by ND-GAIN Index, ranking it 107 out of 181 countries (University of Notre Dame, 2020). Generally, Egypt has a Mediterranean climate, with hot dry summers and mild rainy winters (see Table 1). The delta and narrow valley of the Nile cover 5.5% of the area of Egypt, but both have over 95% of the population and agricultural area.

Incremental hot temperature is also a main climate factor that impacts water resources in Egypt. Compared with other substances, water has the maximum capacity to restrain heat as a coolant before it is converted to having non-water features.

Table 1: Egypt Profile

General Profile	
Gross Domestic Product (GDP)	$ 363.1 trillion in 2020
Current annual growth rate	5.6% in 2020
Population	100.3 million people (2020)
Population growth rate	1.9% (2020)
GDP per capita (current US$)	$ 3600.84 (2020)
Total Area	1,000,000 km^2
Coastline	3,500 km along the Mediterranean and the Red Sea
Arable Land	2.8% (28,000 km^2)

Agricultural Land	4%
Arid Desert	96%
Average Annual Climate Factors	
Precipitation	Average 50 millimeters (mm) to 200 mm (in Alexandria) of rainfall per year
Temperature	20°C (Sinai) - 41°C (Aswan)
Hot wind storms "Khamsin"	+ 20°C (carry sand and dust swept from across the northern coast of Africa)

Source: CAPMAS, (2020); EEAA (2010a); Hereher (2017); USAID (2018); World Bank Group (2021b).

Once the thermal properties of water change, it starts to produce heat and affects the environment, causing other climate change problems, such as glacier sheets melting, releasing the methane stored under the ocean into the air (methane hydrates), causing coral reef bleaching (WMO, 2021), and increasing evaporation and humidity (World Bank Group, 2021b). Hence, the natural flow in the River Nile Basin is extremely sensitive to changes in temperature and precipitation increase (EEAA, 2010a). Both high and low natural flows of Nile water have positive and negative impacts on the water system in Egypt (which is out of the scope of this study). However, Eid, Gad, and Abdel Basset (2019) found that temperature values are gradually increasing from north to south, as a function of latitudes. Their trend analysis revealed that Egypt's temperature values either seasonal or annual are increasing significantly overtime.

This study finds that D&Ls continuously exists even with mitigation and adaptation efforts. The estimated D&L, in Egyptian natural land cover due to temperature, under the BAU scenario is higher than the APA scenario by 70% between year 2020–2039 and by 32.7% between year 2040–2059, respectively (see Table 2). Further, by 2050, the estimated adaptation cost to natural capital D&L ratio would range between 1.2-1.5 percent under the BAU scenario and between 2-4 percent under the APA scenario.

Table 2: Estimated total D&L for natural capital land cover changes due to temperature – (in Million US$)

	BAU scenario		**APA scenario**	
	2020–2039	2040–2059	2020–2039	2040–2059
Estimated D&L due to Temperature	239878.38	278954.55	72598.25	188266.17
Estimated basic 2010 adaptation costs*	2819	4007	2819	4007
Estimated additional adaptation costs beyond 2015**	20.757	20.757	20.757	20.757
Cost to D&L ratio	1.18	1.44	3.91	2.14

*Estimated basic adaptation costs from Egypt NEEDS study (EEAA, 2010b).

**Estimated additional adaptation costs from Egypt's First Biennial Update Report (EEAA, 2018).

Hereafter, this study dives deeper into the results and the different scenarios, using FAO datasets to illustrate (1) the impact of climate factors on the Egyptian area(s) historically, (2) the detailed size of the expected D&Ls under each scenario, and (3) the cost feasibility of the adaptation/mitigation of these impacts to enhance climate resilience.

4.1 The impact of incremental temperature climate on the Egyptian area(s) historically.

Long-term environmental effects of those projects related to climate change, air pollution and ecosystem damages, for example, are highly recommended to use 100+ years timescales to evaluate economic related impact (O'Mahony, 2021). Figures 3, 4, and 5 illustrate the historical trend of climate factors in Egypt from 1960 to 2020. While, table 3 presents screening information analysis about the historical climate factors in Egypt and table 4 shows the correlation analysis results.

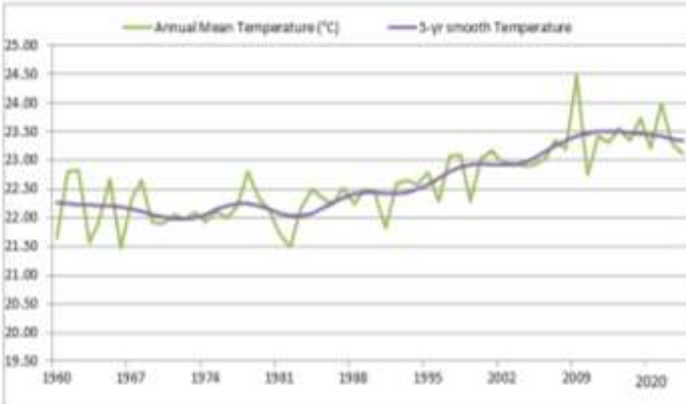

Fig. 3: The historical trend of Annual Mean Temperature in Egypt from 1960 to 2020

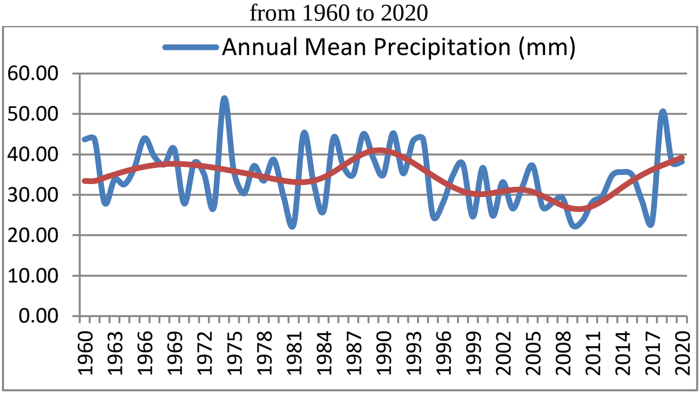

Fig 4: The historical trend of Annual Mean Precipitation in Egypt from 1960 to 2020

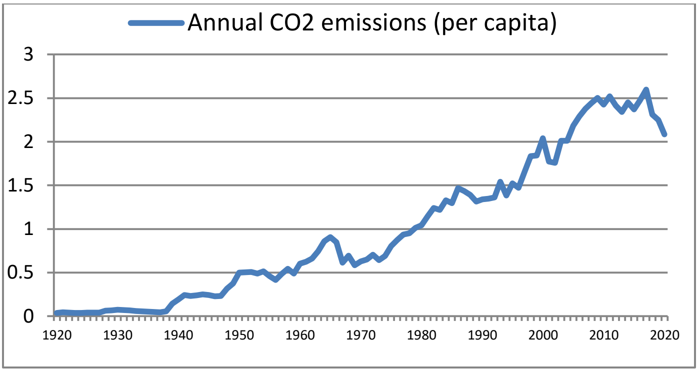

Fig 5: The historical trend of Annual CO2 emissions (per capita) in Egypt from 1920 to 2020

Table 3: Climate factors historical information analysis

	Mean	Dev. St.	Min.	Max.
GHG Emissions (per capita)	1.49	0.65	0.58	2.60
Annual Mean Temperature (°C)	22.59	0.633936	21.48	24.47
Annual Mean Precipitation (mm)	34.57	7.137299	22.50	53.84

Table 4: Correlation analysis between three historical trends of climate factors

	Temperature (°C)	Precipitation (mm)
Annual CO2 emissions (per capita)	0.784782	-0.33302
Annual Mean Temperature (°C)	1	-0.25347

By running correlation analysis between three historical trends of climate factors (table 4), results indicate the existence of a strong positive relationship between CO2 emissions per capita and

Mean Temperature (r = 0.78). On the other hand, there is a negative relationship between CO2 emissions per capita and Mean Precipitation (r = -0.33302) and between Mean Temperature and Mean Precipitation (r = -0.25347). Historical trend analysis outputs support previous studies' assumptions and results (EEAA, 2010a; Hereher, 2017) about the impact of incremental CO2 emissions due to human activities on continuous atmosphere temperature increase and precipitation rate decrease. As well, it gives additional support for the effect of hot weather (higher temperature) on lower rain rates (lower precipitation) that may cause drought overtime in Egyptian land.

Further analysis has been done to investigate the historical impact of temperature and precipitation on Egypt's agriculture area and land cover areas. Egypt's land cover areas have been classified into two categories; natural land cover and artificial surfaces cover. Natural land cover group consists of forest land, grassland, herbaceous crops, tree-covered areas, mangroves, shrub-covered areas, wetland[5], inland water bodies[6] and terrestrial barren

[5] Wetland mainly includes fisheries and shallow water such as bogs, ponds, marshes and swamps. The most important Mediterranean wetland areas are the five major coastal lagoons: Bardawil, Manzala, Burullus, Idku and Mariout.

land cover, presented in figure 6. Where, the second group includes artificial surfaces which involve urban and associated areas.

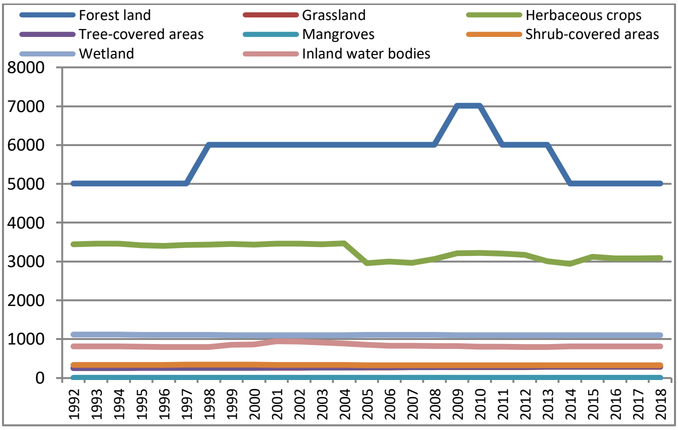

Fig 6: The historical trend of annual change in natural land cover from 1992 to 2018

Table 5 illustrates the correlation between climate factors (temperature and precipitation) and Egypt's land cover areas (natural land cover and artificial surfaces). Correlation analysis has been conducted to determine whether a relationship exists between variables or not and in which direction. The results in table 5 illustrate strong negative relationships between temperature level and majority of sensitive ecosystems; wetland (r= -0.8), grassland area (r= -0.79) and shrub-covered areas (r= -0.69). Additionally, there are moderate inverse

[6] Inland waters include rivers, lakes, streams, springs, groundwater, cave waters and floodplains.

correlations with mangroves (r= -0.54) and herbaceous crops (r= -0.54), as well as, a weak negative relationship with inland water bodies. Generally, inverse relationship indicates that the higher the temperature in the future due to diverse GHG emissions, the more the loss size in land cover hectares and the wider the loss occurrence to related ecosystems. On the other hand, higher temperature is positively correlated with damages size of tree-covered areas (r= 0.78) and forest land areas (r= 0.45) which are more resistant for hot weather, besides, terrestrial barren land area (r= 0.78) is increased. Notably, artificial surfaces (r= 0.69) including urban building, roads and associated areas are positively impacted by hot weather.

For precipitation climate factor, all its relationships with different land cover types, either positive or negative, are weak. However, we can say that all vegetation cover (except forest land) is increased by rainfall increase, whereas desert land area decreases and urban area gets impaired with incremental precipitation. Generally, annual precipitation amount in Egypt is relatively low which may interpret its weak positive impact on land cover types.

Table 5: The historical impact of climate factors on the Egyptian land cover areas

	Mean (1000 ha)	Dev. St.	Min. (1000 ha)	Max. (1000 ha)	Temperature *R*	Precipitation *R*	Hybrid impact R^2
Forest land	5628.84	611.93	5007.25	7010.15	0.45	-0.19	0.35*
Grassland	270.69	11.15	254.62	286.7	-0.78	0.19	0.62*
Herbaceous crops	3242.43	191.82	2939.25	3467.02	-0.54	0.15	0.30*
Wetland	1105.29	6.38	1097.92	1121.07	-0.8	0.17	0.63*
Mangroves	2.01	0.08	1.93	2.15	-0.55	0.14	0.30*
Tree-covered areas	275.11	15.01	254.1	297.18	0.78	0.18	0.61*
Shrub-covered areas	329.65	6.76	321.97	340.37	-0.69	0.23	0.48*
Inland water bodies	829.62	40.01	795.17	942.04	-0.11	-0.1	0.03
Terrestrial barren land	90587.62	118.11	90463.2	90792.87	0.78	-0.27	0.62*
Artificial surfaces	155.1	59.32	78.68	246.95	0.69	-0.15	0.57*

All R^2 (except inland water bodies) are significant at $p < 0.05$.

In reality, both temperature and precipitation have composite effect on land cover. Therefore, a hybrid factor has been created to test the hybrid effect of temperature and precipitation on each land cover type. Following Egidi et. al. (2021), multivariate analysis has been conducted using ordinary least square regression. R^2 from regression analysis has been used to determine the hybrid effect of temperature and precipitation on each land cover type, presented in table 5. Additionally, intercept and R^2 coefficients are generated for prediction purposes in next section. Regression results confirm the significant impact of climate factors; temperature and precipitation on all types of Egypt's cover land areas including inland water bodies where the impact is minimal and insignificant. Inland water bodies consist of rivers, lakes, reservoirs, canals, streams and other landlocked water (FAO, 2021).

Table 6 illustrates the correlation between climate factors; temperature and precipitation, and Egypt's agricultural land cover areas. According to Encyclopedia of Ecology (Lyuri, 2008) and FAO (2016), agricultural land usually consists of permanent crops land, cultivated land and pastures. Cultivated land covers arable land which may include cropland and organic agricultural crops and woody crops and fallows. Data has been collected from FAO database and CAPMAS from 1992 to 2019. Data has been normalized as a percentage of total agricultural land area.

Table 6 presents relationships from moderate to strong between diverse cultivated land areas and temperature, which indicates a potential significant impact of hot weather on the agriculture sector and all types of crops either permanent (r^2= 0.32) or seasonal (r^2= 0.57) and incremental water needs for irrigations. As well, there is a relatively moderate impact on pastures and negative sign that indicates the potential decline in pasture land due to incremental hot temperature along with gradual increase in GHG emissions. On the other hand, the relationship between precipitation and all cultivated areas are weak. However, precipitation is positively correlated with pastures area in strong pattern (r= 0.63). This indicates a potential significant impact of rain on pastures (r^2= 0.54).

To sum-up, historical analysis results strongly indicate the potential impact of climate factors of temperature and precipitation on both natural land cover ecosystems and agriculture land. However, it is notable that the impact is relatively more sever on a number of ecosystems more than cultivated areas, such as wetland (r^2= 0.63), grassland (r^2= 0.62),

Table 6: Historical impact of climate factors on the Egyptian Agricultural land cover areas

	Mean (1000 ha)	Dev. St.	Min. (1000 ha)	Max. (1000 ha)	Temperature R	Precipitation R	Hybrid impact R^2
Agricultural land	91.04	6.58	78.19	100	0.75	0.2	0.57*
Permanent crops*	19.38	5.68	12.72	28.94	0.57	-0.06	0.32*
Arable land	63.85	5.65	54.84	71.03	-0.57	0.06	0.32*
Cropland**	3.51	0.26	3.01	3.85	0.74	-0.2	0.57*
Organic agriculture crops	1.97	0.87	0.4	3.02	0.50	0.31	0.32
Woody crops	0.24	0.06	0.16	0.33	0.52	-0.05	0.27*
Pastures	0.03	0.01	0.02	0.03	-0.37	0.63	0. 54*

* Permanent crops such as palm tree, sugarcane, cotton and trefoil.
**Cropland (temporary crops) such as vegetables and seasonal crops.

All R^2 (except organic agriculture) are significant at $p < 0.05$ and $p < 0.01$

tree-covered areas (r^2= 0.61) and terrestrial barren land (r^2= 0.62) respectively. Furthermore, the highly affected components of agriculture land area by changes in temperature and precipitation levels are cropland (r^2= 0.57) and pastures (r^2= 0.54). Besides, artificial surfaces (r^2= 0.57) are significantly affected by incremental hot and rainy weather. Therefore, the initial results are compatible with the latest IPCC report 2022 that indicated the wider the cascade irreversible effect and severe losses of biodiversity and ecosystem services due to climatic incremental heat levels on the long run.

4.2 The size of the expected D&L due to incremental temperature

Egypt is expected to become generally hotter and drier in the future under the high emission pattern following business-as-usual (BAU) scenario (World Bank Group, 2021b), see Table 7. By mid-century, temperatures are expected to rise between 2°C to 3°C, and the occurrence of highest increases would be in the summer months between July to September, with rapid increases throughout the internal country's regions (USAID, 2018).

Following Egidi et. al. (2021), regression analysis has been conducted using ordinary least square regression. R^2 coefficients were estimated separately for the ten types of land cover and five agriculture land component indicators.

Table 7: Expected Climate factors under BAU and APA emission scenarios

		2020–2039	**2040–2059**	**2060–2079**	**2080–2099**
BAU	Annual Temperature (°C)	+0.6°C to +1.7°C (+1.6°C)	+1.5°C to +3.0°C (+2.1°C)	+2.4°C to +4.5°C (+3.3°C)	+3.4°C to +6.2°C (+4.4°C)
	Annual Precipitation (mm)	-21.6 to +20.1 (-0.5 mm)	-27.3 to +21.0 (-1.9 mm)	-26.5 to +26.7 (-1.6 mm)	-30.2 to +28.2 (-2.9 mm)
	Note: Bold value is the range (10th–90th Percentile) and values in parentheses show the median (or 50th Percentile). **Source**: World Bank Group (2021b).				
APA		**2020–2039**	**2040–2059**	**2060–2079**	**2080–2099**
	Annual Temperature (°C)	(+0.9°C)	(+1.3°C)	(+1.8°C)	(+1.8°C)
	Source: EEAA (2016)				

Outputs regression coefficients are used to assess the predictors' impact (temperature and precipitation) on the dependent variable (land cover and agriculture land) in the future using World Bank Group (2021b) expectations about climate factors under high emission scenario (BAU scenario) and EEAA (2016) third communication expectations about climate factors under low emission scenario After Protective Actions (APA scenario) based on the following prediction models:

$$Y_t = a + b_1 X_{1t} + b_2 X_{2t} + e_t \quad (1)$$

$$\Delta Y_t = \Delta\, b_1 X_{1t} + \Delta\, b_2 X_{2t} \quad (2)$$

Where; Y is the average change in the value of dependent variable in the future t year. X_1 and X_2 are the average change in the value of predictors in the future t year. Regression coefficients values are a and b, and e_t acts as the random error. Where, Δ is the change in predicted value due to change in temperature and precipitation levels in the future. Table 8 and 9 present the expected land cover changes and agriculture land impacts in the future due to changes in temperature and precipitation levels (see Figure 7 and 8) based on prediction model and estimated regression coefficients values.

From table 8, the highest natural land cover loss would be forest land. Forest land is expected to be severely impaired by incremental temperature level accompanied with decreasing in projected precipitation amounts. Losses due to forest land cover change would reach 3.9% of Egypt's total land area, where precipitation may represent the main driving factor rather than temperature. Impaired forests would cause incremental probability in losses for many habitats for animals, birds and insects, as well as, incremental probability for desertification and other climate factors; such as

Table 8: Expected changes (losses and damages) in Land cover under high emission-BAU

	2020–2039		2040–2059		2060–2079		2080–2099	
	Δ in 1000 hec.	%Δ	Δ in 1000hec.	%Δ	Δ in 1000 hec.	%Δ	Δ in 1000 hec.	%Δ
Forest land	-313.17	**-0.31**	-2894.89	**-2.89**	-1781.75	**-1.78**	-3906.75	**-3.90**
Herbaceous crops	-236.81	**-0.24**	-216.72	**-0.22**	-445.39	**-0.44**	-535.86	**-0.54**
Wetland	-13.11	**-0.01**	-16.16	**-0.02**	-26.57	**-0.03**	-34.77	**-0.03**
Mangroves	-0.10	**0.00**	-0.10	**0.00**	-0.18	**0.00**	-0.23	**0.00**
Shrub-covered areas	-9.43	**-0.01**	-5.82	**-0.01**	-16.45	**-0.02**	-17.89	**-0.02**
Inland water bodies	-33.01	**-0.03**	-90.22	**-0.09**	-89.52	**-0.09**	-148.27	**-0.15**
Total natural land cover loss	-605.63	**-0.60**	-3223.91	**-3.22**	-2359.86	**-2.36**	-4643.77	**-4.64**
Grassland	21.11	**0.02**	22.63	**0.02**	41.22	**0.04**	51.84	**0.05**
Tree-covered areas	28.86	**0.03**	32.64	**0.03**	57.13	**0.06**	72.94	**0.07**
Terrestrial barren land	179.74	**0.18**	-89.30	**0.09**	-303.67	**0.30**	-314.52	**0.31**
Artificial surfaces	117.77	**0.12**	149.69	**0.15**	240.66	**0.24**	317.88	**0.32**
Total land cover Damage	347.48	**0.35**	294.26	**0.29**	642.68	**0.64**	757.18	**0.76**

Note: Change in each land cover type is calculated as a percentage of total Egypt land area.
Source: Author.

sand storms. On the other hand, it is notable that mangroves cover land will not change significantly over time, which means it would be a profitable environmental option to expand mangroves area as a natural defense against expected changes in climate factors on the long run. Terrestrial barren land change is expected to increase by 31% in 2100. While, artificial surfaces would be affected by the temperature and precipitation that may causing incremental D&Ls overtime from 0.12% to 0.32% by 2100.

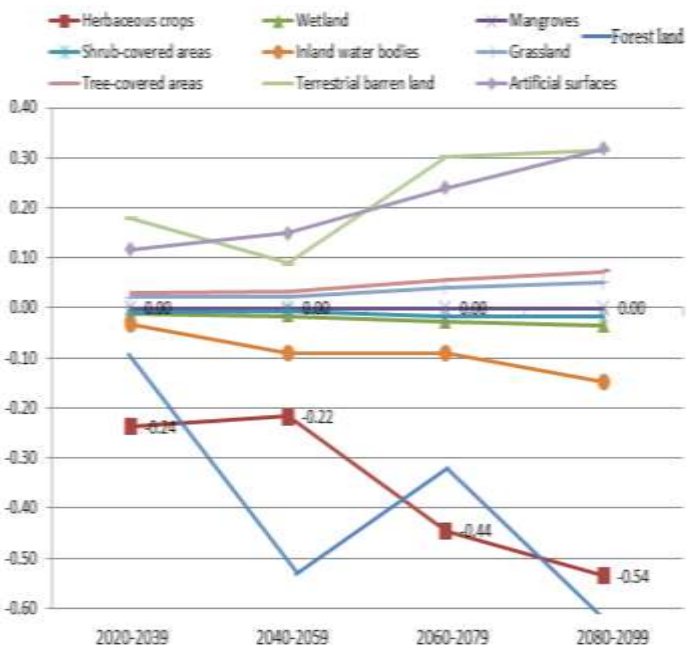

Fig. 7: Expected changes (losses) in land cover under high emission – BAU.

Table 9: Expected changes (losses and damages) in agriculture land under high emission-BAU

	2020–2039		2040–2059		2060–2079		2080–2099	
	Δ in 1000hec.	**% Δ**	Δ in 1000hec.	**% Δ**	Δ in 1000 hec.	**% Δ**	Δ in 1000 hec.	**% Δ**
Permanent crops	464.3	**10.03**	459.9	**13.54**	1735.9	**20.86**	2649.1	**28.05**
Cropland	21.3	**0.46**	11.5	**0.34**	69.1	**0.83**	88.8	**0.94**
Organic agriculture crops	99.5	**2.15**	183.7	**5.41**	467.7	**5.62**	858.5	**9.09**
Woody crops	4.6	**0.10**	4.4	**0.13**	16.6	**0.20**	25.5	**0.27**
Total crops Damage	589.7	**12.74**	659.6	**19.42**	2289.3	**27.51**	3621.9	**38.35**
Arable land	-464.7	**-10.04**	-459.5	**-13.53**	-1736.8	**-20.87**	-2648.2	**-28.04**
Total cultivated land D&L	929.0	**20.07**	919.4	**27.07**	3472.7	**41.73**	5297.3	**56.09**
Pastures	-0.5	**-0.01**	-1.7	**-0.05**	-3.3	**-0.04**	-7.6	**-0.08**
Total Agricultural land D&L (based on the model)	4628.8	**12.00**	3396.3	**8.81**	8321.8	**21.58**	9444.3	**24.49**

Note: Change in each agriculture land component is calculated as a percentage of total agriculture land area, and total agricultural land area as a percentage of total land area, based on expected regression model for expansion trend in total agriculture land area.
Source: Author.

From table 9, total crop damage area including permanent and temporary crops would increase from 12.74% in 2030 to reach 38.35% in 2100. While the total arable land losses would reach 28% of total agriculture area by 2100. Furthermore, total cultivated land D&L will severely increase to be 56% by 2100. Where, all agriculture land covers that are suffering D&L would reach 24.5% out of Egypt's total area by 2100.

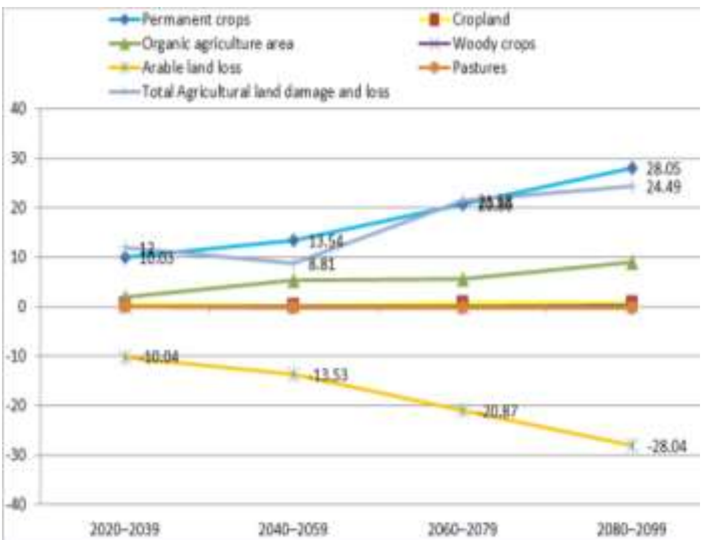

Fig. 8: Expected changes (losses) in agriculture land under high emission – BAU.

Further predictive estimates have been done to calculate expected D&L based on more conservative scenario (APA scenario) where adaptation and mitigation actions will be taken to reduce GHG emissions. Estimated losses and damages using this scenario will be used for evaluating the feasibility of adaptation/mitigation actions in section 4.3.

4.3 The cost feasibility of adaptation/mitigation of these impacts to enhance climate resilience.

Egypt’s cabinet has a planned budget to implement a number of adaptation and mitigation programs. Those programs are expected to reduce the climate change impacts on Egypt’s environmental capitals and diverse economic sectors. Therefore, to find out to which extent the adaptation and mitigation programs will save costs and reduce expected D&Ls, a comparative analysis between BUA scenario and APA scenario will be adopted.

Table 10 and 11 illustrate the comparative results of value changes and cost savings between the two scenarios for temperature impacts using 2018 as a base year[7]. It is notable in table 10 that all land cover types (except forest land) either natural or produced would suffer lower D&Ls under APA scenario. This will give a chance to slower the

[7] Year 2018 is the recent and highest value available from World Bank for natural capital valuation that has been used as a basis comparative year. Value change and cost saving are derived mainly by changes in D&Ls size rather than price movements in the future to reflect the minimum expected value to be damaged.

degradation rate due to climate change factors; mainly incremental temperature, to be over longer periods of time. Forest land keep facing incremental losses under both scenarios due to other climate factors accompanying with incremental heat, such as declining rainfall and sand storms and forest fires.

To estimate the financial impact for incremental temperature under BAU and APA scenarios, national and international databases and reports have been scanned for relevant price rate or value for each type of natural capital of land. Then, value per hectare has been generated and multiplied by each relevant capital land size D&L under each scenario to calculate the degradation in capital land cover and agriculture land due to climate change D&Ls. The World Bank (2021a) datasets for wealth accounts have been used as a proxy to calculate value for each natural and productive capital asset. Future price fluctuation did not be considered because all natural capital values will increase over times, as well as, many types have invaluable and precious environmental values. Therefore, the estimated total value of D&Ls under each scenario are based on a constant 2018 US$ value to measure the minimum expected value would be deteriorated due to changes in D&Ls size, presented in table 12.

Table 10: Percentage of D&L in land cover values under BAU and APA emission scenarios and difference in cost savings

	2020–2039		**Cost savings (Million US$)**	**2040–2059**		**Cost savings (Million US$)**	**2060–2079**		**Cost savings (Million US$)**	**2080–2099**		**Cost savings (Million US$)**
	BAU %Δ	**APA %Δ**		**BAU %Δ**	**APA %Δ**		**BAU %Δ**	**APA %Δ**		**BAU %Δ**	**APA %Δ**	
Forest land	-6.25	-12.2	**-11.38**	-57.8	-64.7	**-13.01**	-35.58	-48.42	**-24.39**	-78.02	-100.1	**-42.28**
Herbaceous crops	-7.67	-3.78	**3.95**	-7.02	-2.57	**4.51**	-14.42	-6.08	**8.46**	-17.35	-2.90	**14.67**
Wetland	-1.19	-0.65	**3.73**	-1.47	-0.86	**4.27**	-2.42	-1.26	**8.00**	-3.17	-1.16	**13.87**
Mangroves	-4.97	-2.52	**0.77**	-4.98	-2.19	**0.87**	-9.54	-4.30	**1.45**	-11.78	-2.69	**2.66**
Shrub-covered areas	-2.92	-1.29	**0.17**	-1.80	-0.07	**0.20**	-5.10	-1.59	**0.37**	-5.54	-0.53	**0.64**
Inland water bodies	-4.08	-3.31	**0.20**	-11.1	-10.3	**0.23**	-11.06	-9.42	**0.44**	-18.31	-15.5	**0.76**
Grassland	-7.36	-3.83	**454.58**	-7.89	-3.86	**519.47**	-14.38	-6.81	**974.19**	-18.08	-4.96	**1689.07**
Tree-covered areas	-9.71	-5.15	**0.45**	-10.9	-5.77	**0.51**	-19.23	-9.45	**0.95**	-24.55	-7.61	**1.65**
Total natural vegetation land cover	-44.2	-32.8	**452.47**	-40.7	-37.8	**517.04**	-62.91	-34.37	**969.48**	-66.33	-57.1	**1681.04**

change												
Terrestrial barren land	0.20	0.08	**398.80**	0.10	0.03	**226.30**	0.34	0.09	**854.57**	0.35	-0.08	**921.10**
Artificial surfaces	-47.7	-26.5	**73087.9**	-60.6	-36.4	**83520.1**	-97.45	-52.00	**156601.3**	-71.28	-49.94	**271450.4**
Total land cover change (D&L)	***-91.7***	***-59.2***	**73939.3**	***-101.2***	***-74.2***	**84263. 6**	***-160.0***	***-86.28***	**158425.3**	***-137.3***	***-107.2***	**274052.5**

Note: Percentage of change in each land cover type value is calculated using 2018 as a base year and constant 2018 US$ value is used as a proxy to calculate cost savings difference between two scenarios.
Source: Author.

Table 11: Percentage of D&L in agriculture land values under BAU and APA emission scenarios and Cost savings

	2020–2039		**Cost savings (Million US$)**	**2040–2059**		**Cost savings (Million US$)**	**2060–2079**		**Cost savings (Million US$)**	**2080–2099**		**Cost savings (Million US$)**
	BAU %Δ	**APA %Δ**		**BAU %Δ**	**APA %Δ**		**BAU %Δ**	**APA %Δ**		**BAU %Δ**	**APA %Δ**	
Permanent crops	-43.8	-26.54	**21171.28**	-57.8	-38.1	**10359.23**	-87.0	-50.06	**47624.69**	-115.7	-51.7	**93692.48**
Cropland	-15.3	-9.07	**1035.35**	-12.2	-5.1	**596.89**	-24.5	-11.17	**2744.12**	-27.33	- 4.2	**5387.95**
Organic	-72.2	-56.8	**3956.91**	-176.3	-	**1154.33**	-	-	**5351.90**	-	-236.1	**52960.62**

	2020–2039		Cost savings (Million US$)	2040–2059		Cost savings (Million US$)	2060–2079		Cost savings (Million US$)	2080–2099		Cost savings (Million US$)
	BAU %Δ	**APA %Δ**		**BAU %Δ**	**APA %Δ**		**BAU %Δ**	**APA %Δ**		**BAU %Δ**	**APA %Δ**	
agriculture crops					158.6		182.8	149.7		293.4		
Woody crops	-61.4	-82.6	**0.13**	-112.0	-93.9	**0.06**	-138.7	-104.7	**0.28**	-165.7	-106.8	**0.55**
Total crops	-43.2	-27.8	**26163.67**	-64.1	-46.1	**12110.51**	-88.99	-55.3	**55720.97**	-122.4	-64.1	**152041.6**
Arable land	-10.7	-4.87	**12680.08**	-15.47	-8.76	**6213.45**	-25.4	-12.8	**28557.47**	-35.1	-13.3	**56151.82**
Total cultivated land	-19.1	-10.4	**38843.74**	-26.2	-16.2	**18323.96**	-41.0	-22.3	**84278.45**	-55.6	-23.1	**208193.42**
Pastures	-1.22	-1.13	**-8.08**	-4.10	-3.99	**4.72**	-3.66	-3.45	**3.86**	-6.42	-6.06	**38.57**
Total Agricultural land D&L	-32.1	-21.8	**38851.82**	-58.7	-56.2	**18328.68**	-47.8	-3.67	**84274.59**	-72.0	-71.7	**208231.99**

Note: Percentage of change in each agriculture land component value is calculated using 2018 as a base year.
Source: Author.

Table 12: Estimated total value of D&L for Egypt land cover both natural and produced capital under each scenario (in Million US$) – Temperature

BAU scenario	**2020–2039**	**2040–2059**	**2060–2079**	**2080–2099**
Direct Loss				
Agriculture Loss	20534.609	11061.635	66390.522	85505.870
Land Cover Loss	959.478	1125.727	1917.935	2475.326
Indirect Damage				
Crops Damage	36162.057	40489.788	140468.895	222282.866
Biodiversity Damage	706.327	364.078	1199.178	1252.003
Soil Damage	17201.401	17063.552	64355.841	98242.380
Produced capital	164314.503	208849.774	335772.508	443511.032
Total D&L	**239878.375**	**278954.554**	**610104.880**	**853269.476**

APA scenario	**2020–2039**	**2040–2059**	**2060–2079**	**2080–2099**
Direct Loss				
Agriculture Loss	78836.649	125557.718	307648.387	349146.058
Land Cover Loss	516.281	619.270	968.135	828.541
Indirect Damage				
Crops Damage	9998.390	28379.281	84747.921	70241.267
Biodiversity Damage	298.259	127.189	324.932	296.656
Soil Damage	4513.243	10845.379	35802.228	42051.990
Produced capital	91226.509	125329.564	179171.214	172060.638
Total D&L	**185389.332**	**290858.401**	**428046.544**	**634625.151**
(-) Total Cost Saving Difference	112791.08	102592.24	242699.93	482284.51
Net Estimated D&L	**72598.249**	**188266.166**	**185346.615**	**152340.637**

Note: Land Cover Loss = Forest land + Grassland.
Crops Damage = Permanent crops+ Cropland+ Organic agriculture crops+ Woody crops.
Biodiversity Damage = Herbaceous crops + Shrub-covered areas+ Inland water bodies + Wetland+ Mangroves + Tree-covered areas+ Terrestrial barren land.
Soil Damages = Arable land+ Pastures. Produced capital= Artificial surfaces.
Source: Author.

The difference between the two scenarios is the cost saving to be deducted or the opportunity cost to be obtained under APA scenario against BAU scenario. This would help for natural capital value retention for a longer time period or to create extra value on the long run. Thereafter, the comparative cost feasibility of adaptation and mitigation programs indicates that significant reduction in total value of D&L for capital cover land range from US$112.8 billion to US$482.3 billion by 2100. As long as the adaptation and mitigation programs are achieving reductions in climate temperature, the possibilities to avoid D&Ls are increasing. This will cause savings for natural and produced capitals to be able to generate income and survive on the long run.

5 Discussions and conclusion

Nowadays, GHG emissions are the most critical global problem. Incremental emissions from land degradation and land use changes are one of the main drivers. Human-induced changes caused by activities such as agriculture intensification, urbanization, overgrazing, and deforestation are key drivers for the decline in natural resources and food supply insecurity in the long run. Therefore, many countries have added scaling down GHG emissions to their top agenda. Adaptation and mitigation efforts should be equitably distributed to reduce the impacts of climate change on both present and future generations.

This study aims to estimate the deterioration in Egyptian assets value for natural land cover. It provides value estimations for potential D&Ls due to land cover changes under two climate change scenarios using the accounting appraisal value approach. The expected model results reveal higher D&L values in the long run under the BAU model, especially temperature climate. This study would help policymakers to enhance climate resilience by considering the amplification impact of any future decisions or policies to be taken not only on expanding the economic (e.g., agriculture) or social (e.g., urban) sectors but also on natural land cover changes over time.

Several research results indicate the probability of incremental desertification risk of the land cover in the future. The incremental rate of forest loss (3.9%) and the magnitude rate of increasing bare land area are strong evidence. Further, a significant impact of incremental temperature on the Egyptian arable land area is expected, although several soil warming experiments are demonstrating variability in significant responses to temperature levels and moisture based on climates and biomes examined.

The highest recent value provided by the World

Bank for Egyptian natural land cover diversity was allocated to agricultural pastureland, followed by wetland. Further, Egypt's wetland habitats are the most important ones in terms of biodiversity. It is second to the Red Sea's coral reefs. Wetlands support the greatest density and diversity of migrating bird species every year. However, there is a historical degradation trend in most Egyptian wetlands due to drain, pollution, overfishing, and overhunting. Furthermore, increasing temperatures are expected to cause more habitats and biodiversity damage, leading to more deterioration in fisheries and tourism. Additionally, forests cover lands are considered the world's lungs. Thus, the higher the impaired forests trend, the more the loss probability of many habitats for animals, birds, and insects and the higher the probability of desertification and other incremental climate factors in the future such as sand storm speed.

The comparative analysis carried out to determine the difference in the size and values of land cover change in the form of D&Ls indicates potential savings for all land cover types in diverse rates in case of protection, except for forest land cover. In the APA scenario, the feasibility of cost indicates that the considerable cost savings as an opportunity cost for further value creation or value retention may reach US$482.3 billion by 2100.

Finally, Egyptian studies on the cost needs assessment of climate change adaptation programs are very limited. They focus only on two sectors—the agricultural and coastal region—which are only a part of the Egyptian natural land cover. Under the BAU scenario, by 2050, the estimated cost needs are almost 1.5% of the total estimated D&L for natural capital and range from 2% to 4% of the total estimated D&L in the APA scenario (see Table 2). This means that leaving a considerable share of other natural land covers without any intervention would lead to severe value deterioration in the form of D&Ls.

To conclude, although, over time, adaptation and mitigation programs may significantly reduce the expected D&Ls in the total natural land cover changes caused by temperature and the rise in the sea level, agricultural land D&L reduction would be relatively low. This proves that natural capitals are very sensitive and connected. Therefore, applying adaptation and mitigation activities alone may not lead to a significant shift in agricultural land, which would weaken climate resilience over time.

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