European policies for confronting the challenges of climate change in water resources

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As confirmed recently by the Intergovernmental Panel on Climate Change, climate change already exists with wide ranging consequences. Europe is as affected as all other regions of the world. Management responses to climate change include the development of new approaches to system assessment and design and the adoption of non-structural methods through mechanisms like the European Union Water Framework Directive (EU WFD) and the new Common Agricultural Policy (CAP). In this article, the evaluation and contribution of recent European policies towards the protection and preservation of water under climate change is discussed. The impact of WFD and EU CAP application in Lake Koronia is presented and discussed.

Keywords: Climate change, EU policies, Greece, Lake Koronia.

Introduction

THE Intergovernmental Panel on Climate Change (IPCC), in its technical report (2008) says: 'Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems'[1].

Adjusting to new climate change conditions requires two main types of responses: adaptation and mitigation. Proactive planning and prediction of unavoidable impacts of climate change into water resources, as well as economically effective measures for reduction of impacts (reduction of greenhouse gases), coordination of actions and cooperation are among the first priorities. It is in this setting that water managers need to tackle an increasingly scarce resource that varies greatly in space and time. Complexity, vulnerability, and uncertainty are key issues to be addressed. Integrated water resources management (IWRM) processes will therefore need to effectively respond to change and be capable of adapting to new economic, social and environmental conditions.

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Climate change will impact water cycle and water resources in Europe and all other regions of the world[2]. There are many regions in Europe that are particularly vulnerable: the entire Mediterranean basin[3] (due to heat and drought periods), the Alps (due to rapid melting of snow and ice), coastal zones, deltas and floodplains (due to sea level rise, intense rainfall, floods and storms) and Europe's far north and the Arctic (due to increased warming worldwide).

Economic sectors that are mostly affected are agriculture, fisheries, forestry, tourism, energy and infrastructure, which depend heavily on climate, weather and environmental conditions[4]. Successful adaptation to the impacts of climate change will depend not only on effective national and European water regulations but also on the ability of current water management strategies to be integrated into affected sectoral policies like agriculture and energy[3,5,6].

EU policies to respond to climate change impacts

Adapting to the new challenge of climate change requires an integrated approach to water management. Attention should be paid to the improvement of understanding and modelling of climate changes related to water cycle and the impacts of climate change to water quality, groundwater, biodiversity, etc. Management responses to climate change include the development of new approaches to system assessment and design, and the adoption of structural and non-structural methods. A number of mechanisms like the European Union Water Framework Directive (EU WFD), the Flood Directive, the Marine Strategy Directive and the new Common Agricultural Policy (CAP) can facilitate adaptation efforts and optimum use of water in Europe.

EU WFD

EU WFD, through planning and integrated management, pricing and true cost recovery, and participation and improved decision making, represents an important step towards sustainable use of water resources in Europe. It is a key legislative instrument in climate adaptation water policies through its step-by-step procedure. The identification of environmental pressures, the application of

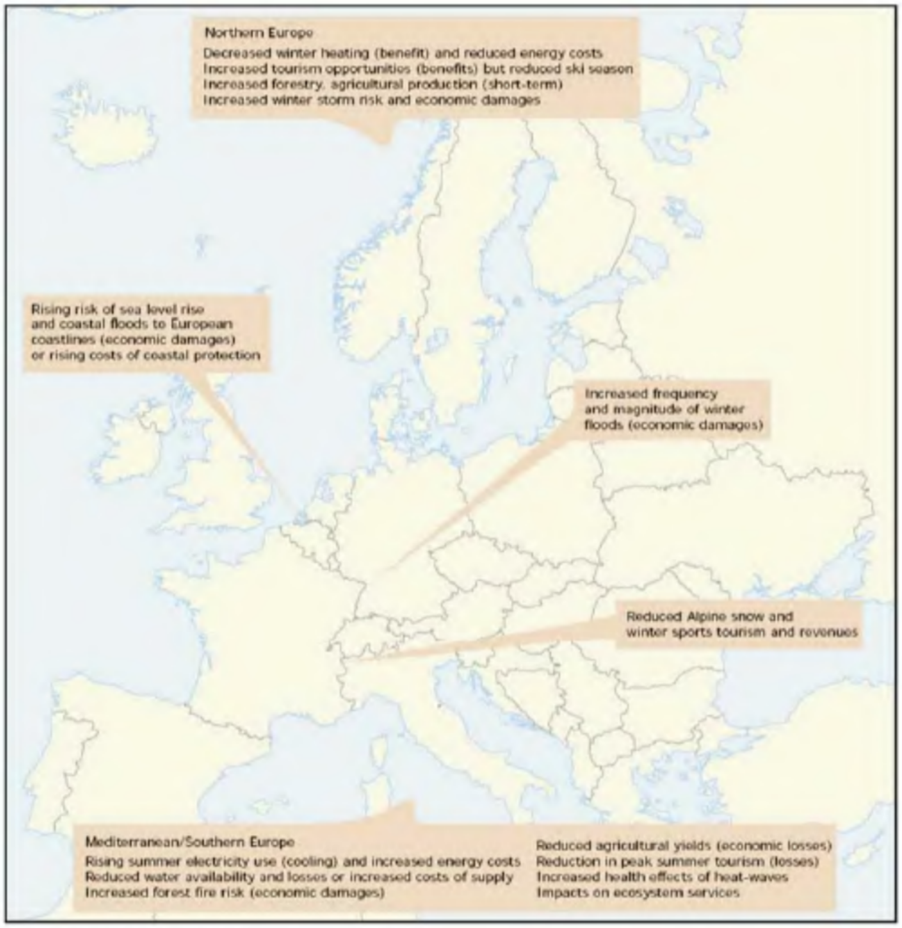
Figure 1. Key past and projected impacts and effects on sectors for the main biogeographic regions of Europe.

river basin approach, the long-term ecosystem management and the river basin management plans (RBMPs) are some of the applied mechanisms to secure sustainable water management and 'good water status' of European waters. The directive defines six-year management cycles until the final goal of good 'water status' in 2015. As it does not directly address issues of climate change consequences, the challenge will be to incorporate measures to cope with climate change as part of its implementation, starting with the first planning cycle for 2009. The implementation schedule of WFD is given in Table 1.

WFD is complemented by the Flood Directive and the policy on water scarcity and droughts.

EU Flood Directive

As the frequency of extreme hydrological events is expected to increase due to climate change, a recent directive has been adopted[7], which requires all EU Member States to focus on the assessment and management of floods and especially on prevention, protection and preparedness[7]. Performance of preliminary flood risk assessment, evaluating the extent of possible extreme events in the future which includes climate change impacts, development of flood maps and provision of Flood Risk Management Plans by 2015 are the main components of the directive. Soft non-structural measures



Source: Based on Watkiss, 2006.

Figure 2. Examples of potential economic effects across Europe.

Table 1. Implementation schedule of EU WFD (www. water.europa.eu/wfd)

Implementation schedule for the Water Framework Directive

	Dec. 2000	**Water Framework Directive goes into effect**
Initial River Basin Analysis	Dec. 2003	**Implementation of relevant legal framework**
	Dec. 2004	**Submit report to European Commission regarding the characterization process**
Establish monitoring programme	Dec. 2006	**Monitoring programmes operational** Submit report to European commission (March 2007)
Implementation of monitoring programmes, elaborate programmes of measures	Dec. 2009	**Programmes of measures and river basin district management programmes have been established** Submit report to European commission (March 2010)
Implementation of programmes of measures	Dec. 2012	**Measures have been implemented** Submit report to European commission
Time to achieve objectives	Dec. 2015	**Good status has been achieved – new river basin management plan comes into force** Submit report to European commission (March 2016)

should be prioritized, i.e. using natural processes to the maximum to reduce flood risks, e.g. working with wetlands, maximizing retention capacities at source, sustainable land use, and spatial planning limiting exposure and vulnerability. However, hard structural flood defences continue to be important to cope with excessive flooding[6].

EU policy on water scarcity and droughts

The present EU action on water scarcity and droughts to develop a common strategy should be closely interrelated with other activities to confront climate change impacts. The challenge of water scarcity and droughts needs to be addressed both as an essential environmental issue and also as a precondition for sustainable economic growth in Europe. As EU seeks to revitalize and reinforce its economy and continue to lead on tackling climate change, devising an effective strategy towards water efficiency can make a substantial contribution[8].

Marine Strategy Directive (MSD)

Europe's marine waters cover about 3 million sq. km. But Europe's marine environment is fast depleting. Pressure on natural marine resources and demand for marine ecological services are often too high. Threats to EU's marine environment include impacts from climate change, commercial fishing, introduction of exotic species, marine pollution from dangerous substances introduced by shipping, oil and gas exploration, and oil spills, nutrient enrichment from agriculture and untreated urban waste water, marine litter, and noise (www.WISE).

The main objective of MSD is in accordance with the WFD goal, to achieve environmentally healthy marine waters by 2020. This will be achieved by establishing marine regions and sub-regions, which will be managed by member states in an integrated manner based on environmental criteria.

In drawing up marine strategies for the waters within each marine region, member states will be required to cooperate closely. Each marine strategy consists of an action plan to be implemented in several stages. Member states will first need to assess the state of environment and the main pressures in their respective marine regions, next determine what can be considered as a good environmental status and then establish targets, indicators and monitoring programmes. Programmes with measures must be drawn up by 2015 to attain good environmental status by 2020 (http://ec.europa.eu/environment/water/marine/index_en.htm).

The goal of Marine Strategy Framework Directive is in line with the objectives of the WFD 2000, which requires surface freshwater and ground water bodies – such as lakes, streams, rivers, estuaries and coastal waters – to be ecologically sound by 2015 and that the first review of the RBMPs should take place in 2020 (ref. 9).

The proposed MSD[7] provides a framework to develop marine strategies to tackle the impacts of climate change on coastal areas. The flexible and adaptive approach that relies upon marine-regions and sub-regions as management units allows for adaptation to the specific impacts of climate change at regional level. EU policy mainly through WFD tried to relate sustainable and integrated approach to managing water resources with water scarcity and climate change (Table 2).

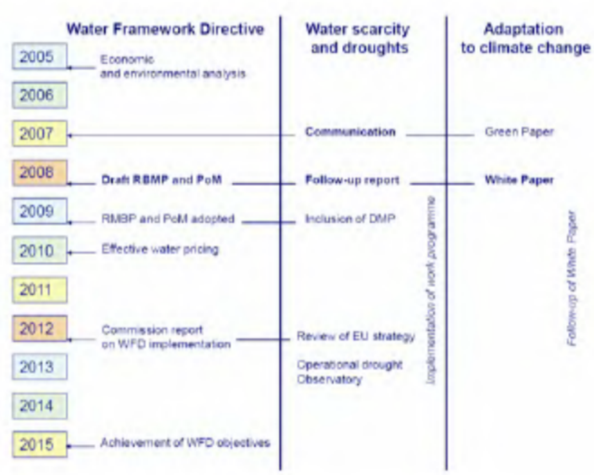
EU Common Agricultural Policy

Agriculture is a significant user of water in Europe and can reach up to 80% in parts of southern Europe, where irrigation of crops accounts for virtually all agricultural water use. In many regions within southern Europe, crop irrigation has a long history and is the basis of economic and social activity. Indeed, the importance of irrigation in some southern locations is such that in its absence great economic hardship would occur and social cohesion may be lost.

In arid and semi-arid areas of EU, including much of southern France, Greece, Italy, Portugal, Cyprus and Spain, irrigation allows for crop production where water would otherwise be a limiting factor. It is important to note that irrigation can and does lead to a range of negative environmental impacts, including water scarcity.

The agricultural sector accounts for 74% of water consumption and for 9% of greenhouse gas (GHG) emissions in EU, thus constituting the second largest emitting sector in Europe after the energy sector (www.water.europa.eu). The identified linkages between agricultural activities and water protection render the necessity to look for synergies in the present agricultural and water policies. The ultimate goals of both policies are environmental protec-

Table 2. EU policies to challenge climate change



Source: EU DG Environment (Bohn Conference 2008).

tion, good water status and water preservation. It is important to identify the pressures and negative impacts that agriculture puts on water. This will facilitate better design of national rural development strategy plans and the successful implementation of WFD which strongly depends on the future development of agriculture, mainly influenced by the CAP.

Since its introduction in the early 1960s, EU CAP has demonstrated a capacity to adapt and change in the face of new challenges. The reformed CAP is an important financial tool, implemented at national level through rural development programmes. These national programmes allow member states to shape policy in a way that can have ambiguous results on water quality and scarcity. EU CAP has been progressively reformed in ways which reduce pressure from agriculture on the environment, and increase benefits. The reformed CAP in 2003, under AGENDA 2000, encourages more environment-friendly farming practices. In the context of their rural development plans, member states are required to link policies on agriculture with protection of environment and to ensure that farmers meet environmental standards.

Agricultural water use across Europe has increased over the last two decades, driven in part by the fact that farmers have seldom had to pay the 'true' cost of water. CAP, giving priority to secure farmer's income and food production, has a share of responsibility as in some cases provided subsidies to produce water-intensive crops using inefficient techniques. But recent CAP reforms have led to a decoupling. In addition, the reforms have strengthened the incentives to farm in an environmentally sensitive way through the adoption of agro-environmental schemes. Such schemes encompass measures related to the water resource, with the potential for a more sustainable use of water by agriculture in the future[10]. The present CAP provides a basic level of income security to farmers as well as a framework for sustainable management of the natural environment in which agricultural activity takes place. The shift from support linked to production to decoupled aid enables farmers to respond to external requirements, to market signals as well as to developments resulting from climate change. Rural development policy offers the member states a range of measures through which they can provide targeted support to activities that contribute to adaptation to climatic changes[11]. The CAP 'health check' represents a further step in directing sustainable agriculture with specific emphasis on climate change mitigation and adaptation, water and biodiversity protection, for which further rural development funding has been agreed upon. The challenge and opportunity for EU and its member states in the period up to the end of 2013 is to make the best possible use of CAP tools available to support adaptation[12].

Future adjustments of CAP and the 'health check' of 2008 could provide opportunities to examine how to better integrate adaptation to climate change in agriculture support programmes. It should be considered to what extent CAP can promote good farming practices compatible with the new climate conditions and which contribute proactively to preserving and protecting the environment[4].

Adaptation is a long-term process which needs to evolve over the coming decades according to climatic trends and by building on knowledge and practical experience. In this process, it is important to further engage and enact all interested parties in the discussion on adaptation needs and in sharing good practices, as farm-level changes are a key component of adaptation[13].

In this context, the review of CAP after 2013 to ensure favourable conditions for the adaptation of agriculture and rural areas will need to be examined. Effective adaptation and adoption of new technologies, which contribute both to mitigation and long-term viability of farming, will require investments and planning efforts beyond the capacity of individual farms. Public authorities will have a role to play in supporting and facilitating climate change adaptation policies[10].

Adaptation and mitigation

Action on adaptation is needed at all levels of administration – local, regional, national, European and international – and requires the involvement of public and private sector as well as individuals. Vulnerability to climate change and the severity of its impacts will be unevenly distributed, so adaptation efforts need to be based on the principle of solidarity between regions, between member states and between the EU and third countries[6].

Effective adaptive measures will include:

- water pricing across all sectors for sustainable water use;
- demand management measures which will improve water efficiency and promote water conservation;
- design and application of drought management plans at river basin scale;
- raising public awareness and information;
- if demand management approach is not adequate, alternative methods such as re-use of water, desalination or treated wastewater are possible solutions; and
- reduction of illegal water use.

The impact of the implementation of EU policies, namely WFD and EU CAP in the Koronia river basin, is presented and further discussed below.

Lake Koronia

Lake Koronia belongs to the hydrologic basin of Megdonia in Northern Greece, which is a part of an interrelated

Figure 3. The area under study.

water resources system including Rechios river, Lake Volvi and shallow and deep aquifers beneath the lake. The lake (Figure 3) is situated 15 km northeast of the city of Thessaloniki. From north to south, it is bounded by mountains of 600–1200 m height above the surface of the sea level and from the west a series of smaller hills of 550 m height. The surface area of the lake until 1985 was 45–49 km^2 with an average depth of 5 m and a water reserve of 200×10^6 m^3 while today the lake's surface area is approximately 30 km^2, its depth is no more than 1 m and the water reserve reaches to only 20×10^6 m^3 (ref. 14).

Lake Koronia, one of the ten most important Ramsar protected wetlands, is complex interrelating environmental, social and economic aspects. The symptoms of the problem are the low water tables in the lake (the volume of water decreased during the last 15 years almost 90%), the deterioration of water quality, the extinction of the existing ecosystem, and salinization of water due to sea water intrusion which makes it inappropriate for irrigation purposes.

The lake suffers from negative water balance as a result of unsustainable human activities that abstract 23×10^6 from non-renewable water resources every year. The master plan for environmental rehabilitation of Lake Koronia, which has been funded by the EC Directorate General XVI, Regional Policy and Cohesion Fund, suggested and outlined measures needed to restore the water balance, the quality of water and maintain the valuable ecosystem in the basin. The proposed measures have been classified into three categories, namely actions and projects connected with restoration of water resources, water quality and lake ecology[15].

Concerning the water resources part of the master plan, the suggested measures are aimed at restoration of the lake water level and of the water balance, through the transfer and artificial recharge of 45 million m^3 water per year. The prevailing alternative solutions for this amount of water to be found will be from:

- the diversion of winter flood discharge of the nearby torrents Sholariou and Lagadikion which normally fall into Lake Volvi;
- the water transfer of 15 million m^3 per year from Aliakmon River; and
- the water transfer from the deep aquifer of the sub-basin of the Koronia lake[14].

The rehabilitation of the lake relies upon a set of combined and concerted measures. The underlying aquifer, and its interaction with the lake play a critical role in the state of Koronia lake water system. Several major studies have been carried out on the surface and groundwater hydrology of the sub-basin Lake Koronia over the past decade. From previous work, the perspectives of the exploitation of the deep aquifer for the restoration of the lake levels were examined. Alternative exploitation plans of the deeper aquifer were examined through a groundwater simulation model of the complex shallow and deeper aquifer system, and the impacts of these scenarios to the groundwater levels and balance were considered and evaluated. It has been proved, that along the vertical stratification of the basin, there are several red clay beds, consisting of red clay, sand and gravel mixtures. Through these beds, a direct hydraulic conduct between the deep and shallow aquifers can be assumed. The deep aquifers are being exploited mostly for irrigation, water supply and industrial purposes through approximately 500 wells. As reported earlier, the recharge of the lake alone from the deep aquifer as one of the options from the lake's master plan, cannot provide a sustainable solution unless it is accompanied by a brave cut-off of agricultural activities across the lake[14].

Today, under the extra pressure posed by climate change, the situation is expected to get worse. A fall in precipitation rate is observed which, in combination, with high evapotranspiration will gradually lead to the reduction of available water reserves[16]. Due to climate change, the negative water balance in Lake Koronia basin will worsen as the reduction of natural inflows will continue (Greek Ministry of Development 2004, www.ypan.gr). What is now needed is an adaptation policy to cope with the reduced water recharge of the river system and the reduced precipitation in the water basin.

WFD provides a consistent framework for integrated water resources management and constitutes a key instrument in climate adaptation policies in relation to water. Through the formulation of RBMP for Lake Koronia, all sectoral activities had been considered. Environmental pressures indicate that not only does climate change represent another 'pressure' altering the quantitative status of the lake and the flow regime but it also affects agriculture due to changes in precipitation and existence of extreme events. The study of the balance between water supply and demand shows that there is an urgent need to provide strong incentives to reduce water consumption and increase efficiency of use in all sectoral activities[14]. Furthermore, water pricing policies and economic instruments can provide a means for water protection but in the case of Koronia Lake neither the 'pollution pays principle', nor expected formulations of water tariffs was implemented. As for active public participation, there are some signs of the farmer's sensitivity towards threats of climate change. As major changes are required in the development model of the region, there is still a long way to go for involving the interested parties in the direction of adopting and implementing measures to reduce climate change impacts in the lake.

Agriculture, which is the main economic activity in the area, as seen from the water balance of the lake (Table 3), is responsible not only for depletion and deterioration of water resources but also for the increase of energy consumption through the operation of powder-driven drillings which, in turn, contributes to the greenhouse phenomenon.

Table 3. Water balance of Lake Koronia[17]

Inflows ($\times 10^6$ m^3 water)	
Surface water	25.3
Rainfall	147.6
Groundwater	22.0
Total inflows	194.9
Outflows ($\times 10^6$ m^3 water)	
Evapotranspiration	107.1
Lake evaporation	30.0
Groundwater outflow to Volvi	5.3
Urban needs	2.1
Irrigation and cattle breeding	70.2
Industrial needs	4.0
Total outflows	218.7
Total	–23.8 * ($\times 10^6$ m^3 water)

Figure 4. Irrigated land around Koronia basin[18].

Intensive agricultural activities also contribute to the increased energy demand; numerous groundwater pumping wells are shown as black dots all around the lake in Figure 4 (ref. 19). Surface irrigation methods as practised account for more than 50% water losses.

Agriculture is also responsible for the deterioration of water quality. The high levels of nitrates, as a result of intensive use of pesticides, have contributed to the eutrophication of the lake and therefore to the degradation of existing ecosystem[20].

Water needed for agricultural purposes is also extracted from groundwater wells. Diesel and electric pumps are used in Lake Koronia area to extract water. There is a sharp increase of pumps through the years (from 280 pumps in 1971 to 2780 electric and diesel pumps in 2008). CO_2 emissions produced are shown in Table 4 (ref. 19).

Energy for agriculture in Lake Koronia

It is estimated that 32% of energy used by boreholes, serves agricultural purposes while the rest is used for water supply[21]. The main reasons for high levels of energy consumption observed for agricultural purposes are:

- increased water needs for cultivation,
- wrong choice of pumping stations, and
- lack of proper maintenance of pumps.

High levels of energy consumption result in higher production cost. The implementation of EU CAP which provides more environment-friendly practices could reduce energy consumption through the application of agro-environmental measures namely replacement of existing crops, the use of less water-intensive irrigation methods and through the fallow in certain crops. In order to explore water and energy conservation measures that could be achieved by implementation of the EU CAP limitations in Lake Koronia, 17 alternative scenarios were formed. Each scenario was produced by a combination of measures proposed by EU CAP to confront climate change. The results[21] showed that a combination of replacement of crops together with the use of contemporary irrigation methods (drip irrigation) promotes water conservation best and enhances soil fertility. In the case of fallow of crops, there is reduction of land which affects farmer's income. The replacement of surface irrigation methods with less water-consuming ones (drip irrigation) conserves approximately 20.3×10^3 m^3 of water but has a significant initial cost. Among the scenarios, the best one achieves 22.2% water and energy conservation and suggests a partial replacement of fodder (50%) with maize and at the same time replaces surface irrigation method with drip irrigation. One of the scenarios provided higher percentages of water conservation, up

Table 4. Relation between pumps and CO_2 emissions

Pumps				
Type	Number	Energy consumed (MWh)	Oil consumed (l)	CO_2 emissions (kg)
Electrical	2372	332	–	57.120–91.392
Diesel	408	57	19111	243.083
Total	2780	389	19111	300.203–334.475

to almost 40%, but has drawbacks in terms of economic efficiency.

It is important to note that both WFD and EU CAP can help reduce the major water problems of Lake Koronia but cannot solve it without the aid of technical intervention. Both supply and demand measures should be implemented. Importance should be given to increase awareness and build consensus among stakeholders to enhance their ability to further understand the importance of the new conditions because of climate change. In the case of Lake Koronia, the following priorities should be considered:

(i) digging of new boreholes in the greater Lake Koronia area should be stopped;
(ii) limit the expansion of agricultural activities and promote alternative ways to sustain farmer's income;
(iii) provide incentives for rural development activities, based on new CAP guidelines;
(iv) irrigation should be done during evening hours when evaporation is low; and
(v) the use of renewable energy sources should be promoted[19].

Conclusion

Adaptation is a challenging task because the severity of climate change impact varies widely from region to region. The impact depends on factors such as the region's physical vulnerability, degree of socio-economic development, natural and human adaptive capacity, health services and disaster surveillance mechanisms.

The current EU water policies provide ample tools to begin with adaptation to climate change. They have to be developed further through integrated approaches at all levels of governance.

As Evan Vlachos says: 'The new paradigms of complexity and interdependence need not freeze us as to optimal solutions; reasonable approximations are parts of necessary trade-offs and of efforts to balance the relationship between "ideal" or desired futures, and "real" or pragmatic considerations of unfolding changes and practicable solutions.'

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