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A Review on Water-Saving Agriculture in Europe

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Abstract

This paper aims to analyze the research on the current situation of water-saving agriculture development in Europe. Water-saving agriculture in Europe started early, governments and farmers in various countries have a strong awareness of water-saving in agriculture and have achieved certain results. Due to the global spread of the COVID-19 pandemic, the lack of up-to-date field research, the complexity of various agricultural disciplines and categories, and the lack of information sharing, the current cognition of recent progress in the development of water-saving agriculture in Europe is not comprehensive enough. This paper selects four representative European countries: Spain, Germany, Italy, and Denmark as the research objects. Based on the existing research of Chinese and Western scholars, this paper analyzes and studies the current situation of water-saving agriculture in Europe. It has far-reaching significance for other countries in the world to have further development in water-saving agriculture and to protect water resources.

Keywords

European Agricultural Water, Water-Saving Agriculture, Water Resources

1. Introduction

For any country and region, the issue of water resources can only be considered after the economy has developed to a certain extent. The 2020 European Environment Agency data shows that the agricultural water in the EU's annual water consumption has reached 50% in the past 30 years after the implementation of the Common Agricultural Policy (CAP), and may increase in the future. Therefore, agricultural water-saving has become an important part. European countries have a long history of industrial and agricultural development, and their economic level ranks first in all continents, providing many strong conditions for the development of water-saving agriculture. However, many countries are still facing the dilemma of lack of fresh water resources and uneven distribution of water resources. Supporting the huge agricultural development of the entire continent with its own existing water resources is not as simple as imagined. For example, how can climate advantages be maximized in water-saving agriculture? How does water-saving agriculture in European countries work in livestock farming? What is the impact of water prices on European agricultural development... On the above issues, domestic and foreign experts and scholars have conducted extensive and in-depth research in the past 30 years, and achieved considerable results.

Based on these, this study summarizes the agricultural water-saving methods of different European countries, so as to highlight the advantages and disadvantages of water-saving technologies adapted to local conditions in each country, so as to contribute to the development of water-saving agriculture in Europe. At the same time, these results also correspond to the relevant agricultural water-saving policies. This paper aims to help European governments effectively utilize the rigid conditions of water-saving agriculture, and exert their own initiative on the basis of EU water-saving policies according to their own characteristics, so as to help countries around the world. The development of water-saving agriculture provides valuable experience.

2. Current Condition of Water-Saving Agriculture in European Countries

2.1. Spain: The Transformation from "Barren Land" to European "Vegetable Basket"

Water-saving irrigation area of Spain ranks second in the world after the United States, and is the largest irrigation country in Europe [1]. Its irrigation area management has been automated, and its management level is world-class. Due to the lack of water and few rivers, it has been focusing on the construction of farmland water conservancy facilities, strengthening water resources management and developing water-saving agriculture.

2.1.1. Government's Attention

Driven by the EU agricultural market, groundwater-irrigated agriculture in Spanish water-scarce regions has switched from alfalfa and maize to less water-intensive, high-return crops such as grape and olive. On the one hand, the Spanish government and agricultural propaganda departments make full use of the abundant seawater resources for desalination [2]. On the other hand, Spain promotes the water-saving technology of facility agriculture, by the adjustment of greenhouse structure, soil improvement, water-saving irrigation, etc. In recent years, the benefits of its greenhouse horticultural crops per ton of water are as high as 12.5 Euros, equivalent to 92.5 Yuan [3]. At the same time, irrigation infrastructure of Spain, including water storage tanks, water purification stations, water pipelines, irrigation pump stations and other equipment investment, in addition to the facilities required by farmers in the fields, is basically carried out by the European Union and the central and local governments of Spain undertake [4], and most of them are free of charge.

2.1.2. Promotion of Advanced Technology and Equipment

Cai Hongyi (2017) and other scholars compared the construction of agricultural water-saving irrigation in Spain, Japan and the United States and argue that in order to solve the contradiction between the supply and demand of agricultural water resources, the Spanish government has launched a series of reconstruction plans in irrigation to improve agricultural production efficiency and develop modern irrigation. In these plans, the government and civil organizations will jointly invest in the old irrigation areas reforming, replacing traditional canals with pipeline, transforming surface irrigation technology into mechanized irrigation technology, and giving priority to the transformation of aging key projects and the upgrading of modern technology in field projects. Gradually reduce the number of new large-scale irrigation projects, and transform the original traditional extensive expansionary development path into a technology upgrade based on engineering technology content [5]. Most of the farmland in Spain has adopted advanced irrigation technologies such as sprinkler irrigation, drip irrigation and infiltration irrigation, and has achieved automation, digitization, and remote control in soil moisture monitoring, precipitation monitoring, field experiments, and crop planting [6].

Almeria (European "vegetable basket"), located in the south of Spain. Although it is coastal, it is on the leeward slope of the westerly wind and is affected by the subtropical high pressure in the season. It is dry year round, and it is only 213 mm of precipitation, so, water bills are very expensive. In order to cut costs, the Spanish government has adopted a series of water-saving measures in agricultural production: They require farmers to build rain pools、build rain storage pipes on the roof of greenhouses and support farmers to use drip irrigation and fertilization systems; implements national policies; relies on geographic advantages, desalinates Mediterranean seawater; drills wells or canals in mountainous areas... At the same time, in order to slow down water evaporation and follow the concept of development of water-saving agriculture, all farmland in Almeria area is plastic and steel frame greenhouses, to ensure the humidity required by crop growth to a certain extent and realize water saving in the process of crop water conversion.

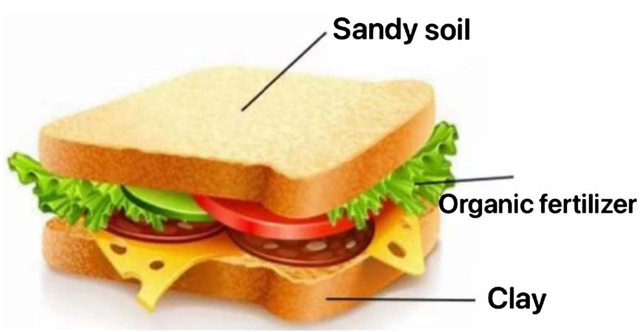
When inspecting the facility horticulture industry in Almeria, Spain, Bao Shunshu (2019) pointed out: the soil parent material in Almeria is sand and gravel, local farmers use sand, organic fertilizer and clay to make the new soil profile show a "sandwich" structure: the surface layer is the imported sand, the middle layer is fermented organic fertilizer, and the lower layer is clay [7]. The upper layer of sandy soil has good water permeability and air permeability, which can quickly absorb water and fertilizer to prevent ground runoff; the middle layer of organic fertilizer can enhance the fertilizer, water retention and buffer capacity of soil, reduce the fixed loss of nutrients, thereby creating good soil conditions for the growth of crops; the lower layer of clay soil can maintain water and fertilizer to avoid nutrient, water seepage. The "sandwich" structure (as shown in **Figure 1**) scientifically promotes the water cycle of crop roots under limited natural and geographical conditions from a new perspective, maximizes the efficiency of irrigation water use, and improves the unilateral aspect of water output in agricultural production to achieve the development goal of water-saving agriculture.

2.1.3. Scientific Management

Angel Paniagua Mazorra (2001) pointed out that agricultural water-saving irrigation management system of Spain adopts appropriate decentralization between the central and local governments. The government is mainly responsible for formulating agricultural water-saving irrigation policies, implementing specific water-saving irrigation construction projects, supervising and guiding large-scale water source projects, construction and management of key water delivery projects; the main responsibility of the civil organization—water user association is to be responsible for the construction and management of irrigation projects [8]. FG Gomez (2012) and Zhu Qingyun (2012) discussed the "European Water Framework" in detail, arguing that the Spanish agriculture generally adopts the mode of forming farmers' associations for farmers' self-management, and farmers' associations and government departments obtain water use through negotiation. The right to use water is distributed democratically within the farmers' association to popularize the idea of water conservation [9].

2.2. Germany: Water-Saving Agriculture in an Industrial Powerhouse

Germany has a temperate oceanic climate, with a rainfall of 500 - 1000 mm [10]. The northeastern part (formerly East Germany) is relatively less, and the water resources are relatively abundant, but the distribution is not very uniform, which leads to 97% of its arable land is rain-fed agriculture. Irrigation water only accounts for 0.25% of the total water consumption. Ren Chunxia (2004) mentioned in her research: Germany stores and recharges the rainy season floodwater to



Source: The author made his own according to the characteristics of agricultural soil in Almeria.

Figure 1. Distribution map of "sandwich" soil structure.

the ground and uses it for farmland irrigation, their research on comprehensive utilization of rainwater has always been at the forefront of the world [11]. In theory, Germany is not a country with a shortage of water resources, but it pays special attention to ecology and water conservation [12]. The level of water-saving agriculture is also very high, which is of great research value.

2.2.1. Agricultural Mechanization Driven by a Strong Industrial System

As the fourth-ranked developed country in the world, Germany's GDP is three times that of China's total, but it "feeds the whole of Germany with 2% of the agricultural population". A strong industrial system drives strong agricultural mechanization, and Germany's digital agriculture is comprehensive, so its water-saving agriculture is also fully intelligent [13]. For example, Wang Shuting (2020) pointed out that the temperature, soil quality, precipitation, humidity and other data of each acre of arable land should be transmitted to the cloud for processing on the cloud platform, and then the generated relevant soil data will be processed on the cloud platform. The data of moisture content and required moisture are sent to intelligent large-scale agricultural machinery according to the weather conditions in a short time (with or without rainy weather), and they are instructed to carry out refined operations, including irrigation or moisturizing, heat preservation, etc [14].

Rain-fed agriculture attaches great importance to the utilization rate of precipitation, and the relevant agricultural departments of Germany have adopted various measures to improve the soil's ability of absorbing precipitation. For farmers, they are more concerned about the available field water capacity, that is, the amount of water that can be stored in the field soil and absorbed and utilized by crops in the precipitation. In Chen Zhangquan (2017)'s research on the protection and sustainable utilization of agricultural water and soil resources in Germany, he pointed out that the German government agricultural department will release information on the water content of the crop plough layer soil, but many farmers will install soil moisture monitoring instruments on their farms to monitor real-time measurement of soil moisture changes [15]. At the same time, 100% of Germany's agriculture has achieved water-saving irrigation [16], of which, sprinkler irrigation accounts for about 80%, mainly used for field crops such as wheat and potatoes; drip irrigation accounts for about 20%, mainly used for vegetables and fruits. Due to the complete elimination of surface irrigation irrigated agriculture has high water use efficiency.

2.2.2. Reverse Forced Water-Saving Irrigation Mode

It is worth mentioning that another important reason for the continuous improvement of agricultural water use and utilization in Germany is that the government mainly promotes farmers to adopt advanced irrigation technology through market means—water price regulation to achieve the purpose of water saving. In 2017, Dortmund's price of water is as high as 2.9 Euros (21.5 Yuan) per cubic meter of water. Even water companies and agricultural irrigation and water pipeline companies do everything possible to prevent leakage of water pipelines. In addition to, the price of crops in Germany is not high, the price of water-saving irrigation equipment is high. Farmers can only reduce the cost of irrigation water to reduce planting costs. This has formed a forced water-saving irrigation mode, which makes the agricultural water-saving concept deeply rooted in the hearts of the people.

2.2.3. Agricultural Production Activities Are Regulated

In order to protect groundwater, Germany has not only formulated strict production license application procedures for agricultural material production enterprises, but also made clear and strict regulations on fertilization and spraying pesticide of farmers. When farmers use certain pesticides or fertilizers on crops, they must keep records so that the relevant departments can check and control them. B. Köstner (2014) emphasized many times in the study of plant production: Germany promulgated fertilization regulations as early as 1996, stipulating that any fertilization behavior is prohibited from November 15th to January 15th of the following year. Phosphate fertilizer, Potassium fertilizer once every three years to avoid crops not absorbing and affecting groundwater and soil [17]. Zeng Zhe (2020) stated: According to the policy, if farmers contribute to the protection of the natural environment and biodiversity, engage in agricultural production activities in a sustainable manner, they can receive green compensation payments. Once violations of cross-compliance (highlighting the protection of water, soil, and biodiversity) are found in agricultural production, green direct payment funds will be deducted ranging from 1% to 20% as appropriate. Scientifically coordinate the amount of water intake and replenishment. When extracting groundwater as a source of irrigation water, the extraction rate should be determined according to the rate of groundwater replenishment to ensure that the groundwater level does not drop and achieves a balance between in and out.

2.3. Italy: Mature Water-Saving Irrigation Facilities and Technologies

Italy belongs to a typical Mediterranean climate in southern Europe, with different periods of rain and heat, arid climate and scarce precipitation when crops are growing. Therefore, the Italian government has always attached great importance to the development of water-saving agriculture, and relevant universities and scientific research institutions have also been committed to the research and development of water-saving irrigation technology, which has been extended to agricultural production (Bozzola Martina *et al.*, 2018) [18].

2.3.1. The Maturity of Water-Saving Irrigation Machinery

Italy regards water-saving irrigation as the core of national water-saving agricultural development. It is conceivable that Italian water-saving irrigation is quite successful. Sun Bo (2002) and Wu Zhengang (2002) pointed out in their research that sprinkling and micro-irrigation technologies had been introduced from the

United States and Israel in the 1960s, and it only took about 10 years to overcome the shortcomings of truss-type sprinkling irrigation and micro-technology. And the reel type sprinkler irrigation machine was also developed, which solved the water-saving irrigation problem of field crops (wheat, corn, soybean, etc.) [19]. Up to now, the reel-type sprinkler irrigation equipment in Italy has been quite mature, and the reel-type sprinkler irrigation in the domestic plain area has reached 60% - 70%.

2.3.2. Adding Water-Saving Facilities in Farms

With the continuous progress of science and technology and industrialization, Italian farms are constantly adding water-saving irrigation facilities (see **Table 1**). At present, the drainage and irrigation channels in Italy are 181,312 kilometers long. The total irrigation area under the management of the National Irrigation Committee has reached 3.3 million hectares. Among them, the sprinkler irrigation area is 1.683 million hectares, the micro-irrigation area is 660,000 hectares, and the total water-saving irrigation area is 2.343 million hectares, accounting for about 71% of the actual irrigated area (see **Table 2**). And the coil-type sprinkler that is used for sprinkler irrigation saves water and energy significantly. It only needs 450 cubic meters of water per hectare at a time. In Europe, crops

Table 1. Scale of additional irrigation facilities on Italian farms.

Facility	Scale
Total length of irrigation and drainage channels	181,312 km
Total length of river bank protection	9233 km
Number of dams and various forms of weirs	22,839 seats
Number of pump systems	754 seats
Number of water lift irrigation systems	1301 seats
Drainage area	7,000,000 hectares

Source: The author's self-made according to the "Italy 'Agricultural Water-Saving Irrigation Technology Training' Report".

Table 2. Types of water-saving irrigation in Italy.

Type	Area (hectares)	Proportion (%)
Flood irrigation	198,000	6
Field artesian irrigation	759,000	23
Sprinkler	1,683,000	51
Drip irrigation	660,000	20
The total area	3,300,000	100

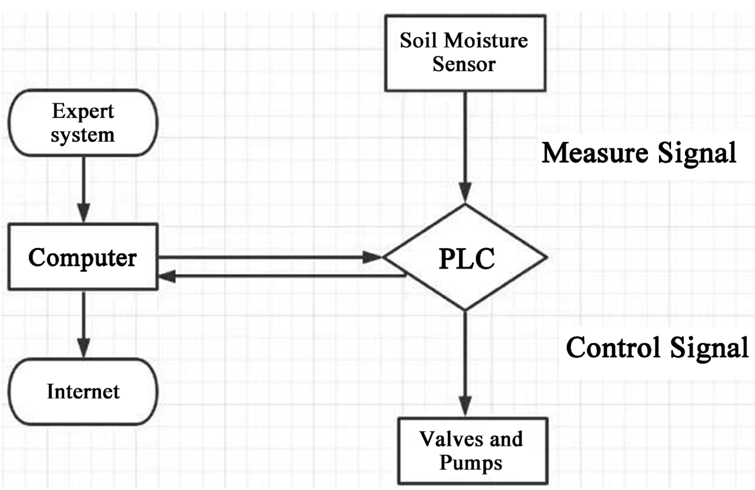
Source: The author made his own according to the "Italy 'Agricultural Water-Saving Irrigation Technology Training' Report".

such as wheat and corn are generally sprinkled 5 times per season, and the annual water consumption is 2250 - 3000 cubic meters per hectare, less loss, high utilization rate of irrigation water, it can save more than 50% of water.

2.3.3. Develop and Use Precision Watering Technology

In addition, Italy made full use of EU funds and cooperated with the implementation of the EU's seven-year plan (2014-2020) in 2013. Zhang Manjie (2014) emphasized in her research on the development of Italian agriculture: Italy has always used EU funds to provide farmers with a lot subsidies from every aspect [20]. In terms of precision agriculture, the key is precision irrigation and fertilization technology [21], which has been used in 5% of Italian farms. The research of Zhou Xiaoping (2008) shows that: Italy uses the advanced PLC automatic control technology to combine with irrigation (as shown in **Figure 2**) to achieve the purpose of intelligent, accurate and even water supply [22]. At the same time, sensors for monitoring water, humidity, and soil composition are arranged in the soil, the remote monitoring system is used to analyze, calculate the amount of water to be irrigated, analyze the amount of fertilizer required by the soil, and give the prescription map of each piece of land, so as to ensure accurate irrigation, use fertilizers and pesticides. This way can achieve the purpose of saving water and ensure the water quality of irrigation [23].

However, no matter whether the irrigation method at the end is drip irrigation or sprinkler irrigation, the water quality requirements of this precision irrigation technology cannot be ignored. Because in addition to the high investment cost, the biggest disadvantage of sprinkler and drip irrigation is that it is easy to block. However, this irrigation technology has strong terrain adaptability, so experts are working hard to make up for its shortcomings, such as adding lamination filters or choosing sprinklers with strong anti-clogging and stable performance.



Source: The author's self-made according to the "Automated Seedling Raising and Water-Saving Irrigation Techniques of Italian Lettuce".

Figure 2. Italian water-saving irrigation technology route.

2.4. Denmark: Treatment of Groundwater and Wastewater

Denmark, which is a traditional agricultural country, is a "green kingdom" for global environmental protection. Its goal is to become a 100% renewable energy country in the mid-21st century. One cannot help but wonder, such a "turn every drop of water into a resource" environmentally friendly country, what is its water-saving agriculture like?

2.4.1. Large Pig-Raising Country Dominated by Animal Husbandry

The Kingdom of Denmark is located in northern Europe and consists of more than 480 islands. The average annual precipitation in the territory is 600 mm. The climate is changeable, and drought often occurs in spring and summer. Such climatic conditions are not conducive to agricultural production [24], but Danish agriculture still has strong competitiveness in the international market, its agricultural area accounts for two-thirds of the territory of country. Agriculture is based on animal husbandry, water accounts for more than 70% of total water consumption. Its livestock and poultry breeding industry is mainly pig raising. Each Dane can share nearly 6 pigs on average. It is the only country in the world with more pigs than people [25], and each pig consumes about 200 L of water.

2.4.2. Groundwater and Wastewater Treatment: The Core of Water-Saving Agriculture

Due to the scarcity of surface water, Denmark uses groundwater almost completely. Over-exploitation of groundwater will lead to many irreversible environmental problems: the groundwater level continues to decline, the groundwater level funnel continues to expand, and the groundwater volume decreases, resulting in land subsidence, ground collapse, seawater intrusion and other serious consequences of ecological environment deterioration. The United States, China, Japan and other countries and regions have already learned a bloody lesson. Therefore, the relevant departments of the Danish government pay special attention to the limit and the efficiency of groundwater use.

Under the strict water management, Danish water leakage rate is far below the international average. Some countries have a water leakage rate of 40%, while Danish water leakage rate is only 8%. In addition to, Denmark will regard the recycling of groundwater and wastewater treatment as the heart of water-saving agriculture. For example, in the research of Cui Ningbo (2020) and Ba Xuezhen (2020), it was mentioned that in order to protect groundwater, Denmark has strictly controlled the use of pesticides since the 1980s, and strived to minimize all kinds of pollution [26]. Slaughterhouses and farms in Denmark, as well as cooperative enterprises in the production and processing of agricultural products, purify and recycle waste- water from production lines in order to prevent nitrogen loss and contamination of groundwater resources [27], the fertilizer for pigs should be fermented and applied to the field at the specified time (twice in spring and autumn), while the organic matter in the wastewater is concentrated in the sludge, the phosphorus extracted from the wastewater or sludge can become fertilizers.

The remaining mine- ral and organic components in the sludge can be used as soil conditioners or additional fertilizers [28]. Guo Hongpeng (2015) and Xu Beichun (2015) did in-depth research on the above. In this way, while protecting and saving groundwater resources, a circular organic water-saving agricultural system is also formed.

2.4.3. Rising Water Prices

At the same time, Denmark has the highest water price in the world, with an average of 8 euros per cubic meter. Industrial, agricultural and living water use one price, 34% of the high water price is used for water supply and 66% is used for wastewater treatment [29]. Guo Xin's (2020) study shows that the cost of wastewater collection and treatment is usually twice the cost of water abstraction and water supply, adhering to the principle of "who pollutes, who treatments" [30]. For decades, the price of water in Denmark has continued to rise. Even so, the productivity and efficiency of Danish agriculture have not been affected. Especially as a major agricultural country, its agricultural efficiency is still leading the world, and its experience in water-saving agriculture is of forward-looking significance.

3. Conclusion

According to the above review, it can be seen that under the leadership of European cultural and creative industries and experienced economy, European countries have formed water-saving agricultural development models suitable for their own national conditions after nearly 20 years of exploration and practice. Agriculture, as a secondary production sector in Europe, has a very high level of modernization. On this basis, a notable feature of the EU's agricultural policy is that the agricultural support policy has been comprehensively shifted to encourage the intensive use of agricultural resources and environmental protection. All European countries pay special attention to the development of water-saving agriculture and the efficient recycling of water resources whether they lack of water or not. The market-oriented reform of the EU agricultural knowledge innovation service system has reduced the pressure on public finances, promoted the process of agricultural modernization and agricultural innovation, accelerated the pace of research and development of advanced technologies for water-saving agriculture to a certain extent through the diversification of service supply and the specialization of technology supply.

4. Prospects

Although the condition of groundwater is fairly good, condition of surface water is "critical". In many places of Europe, irrigation agriculture is the center of the local economy. Sustainable and efficient agricultural water use is critical, not only to protect the environment, but also to ensure that agriculture can be profitable. Therefore, governments need to invest more in technology and management measures to improve water-use efficiency in the agricultural sector. Traditional water resource management in Europe focuses on water supply, and conventional agricultural water supply is achieved through the integrated use of reservoirs, water transfer within the basin, and increased groundwater extraction. Now there are about 7000 large reservoirs in Europe, their water storage capacity accounts for 20% of the total freshwater resources in Europe [31]. At the same time, Europe also needs sustainable water resource management driven by water demand, focusing on water source protection and efficient water use, not only to meet the water needs of the agricultural sector, but also to meet the healthy water needs of the water ecology. More sustainable and integrated management of water resources, the "demand-driven management model", has been reflected in water-related policies and legislation, for example, the European Water Framework Guidelines call for "long-term protection of available water sources to promote sustainable water use".

Europe has long recognized the challenges posed by water scarcity and drought, and noted the magnitude of the problem, developing a series of strategies focused on demand management to improve agricultural water use efficiency. The above-mentioned national development of water-saving agriculture is involved. Such as: setting the irrigation time according to the water demand law of crops; using more efficient irrigation techniques, such as sprinkler irrigation and drip irrigation; or changing the variety of crops to reduce its demand of water; avoiding peak of water consumption as much as possible during the midsummer period when there is less rainfall. At the same time, other agricultural water-saving methods: such as advocacy and guidance to farmers is also a good practice to improve agricultural water use efficiency; national and European Community funds, including funds under the European Union Common Agricultural Policy, play a key role in reducing future agricultural water use; the introduction of biochemical energy and growing bioenergy crops does not increase agricultural water use, especially in water-scarce regions, it should be an opportunity to reduce agricultural water demand. From this point of view, biochemical energy crops should have low water demand, or have strong drought tolerance, such as sorghum, sugarcane and so on.

The issue of water conservation in European agriculture, like environmental protection, will be a hot issue in European and even global development for a long time in the future. There will be harvests in this process, but it will also be accompanied by big and small challenges. The development of water-saving agriculture in Europe has a long way to go.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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