

## Dry ports for achieving the sustainability of agri-food supply chains

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A dry port is an inland intermodal terminal directly connected by road or rail to a seaport, providing a hub for the transshipment of cargo to and from the seaport (Roso et al., 2009). In recent years, the development of dry ports has become increasingly important due to several trends in global trade (Tadić et al., 2021). One of them is growing demand for intermodal transport. With the increasing volume of global trade, there is a growing demand for intermodal transport that integrates multiple modes of transportation, such as road, rail, and sea (Behdani et al., 2020). Dry ports provide a seamless connection between these modes of transport, making it easier and more efficient to move cargo (Zain et al., 2022). Another trend is shift towards regionalization of trade. There is a growing trend towards regionalization of trade, where countries are increasingly looking to develop trade relationships within their own region (Wang & Sun, 2021). Dry ports provide a key infrastructure element for regional trade by connecting inland regions to seaports, allowing for more efficient and cost-effective movement of goods. Increasing importance of e-commerce is another important trend. The rise of e-commerce has led to a significant increase in parcel deliveries, particularly small and medium-sized parcels (Xiao et al., 2011). Dry ports are well-suited to handle these types of deliveries, as they can provide efficient last-mile delivery services to customers. Lastly, there is a trend of requests for greater efficiency and sustainability. Dry ports can help improve the efficiency and sustainability of global trade by reducing the distance that cargo needs to travel and optimizing the use of transportation modes (Jeevan et al., 2022). This can lead to reduced transportation costs, lower carbon emissions, and faster delivery times. The development of dry ports is significant because it can help to reduce bottlenecks at seaports (Krstić et al., 2019), improve the efficiency and sustainability of global trade, and support the growth of regional trade relationships (Tadić et al., 2019). As a result, there is likely to be continued investment in the development of dry ports in the coming years.

Dry ports are important for sustainability for several reasons. By providing a hub for the transshipment of cargo, dry ports can help to reduce the distance that goods need to be transported (Fazi et al., 2020). This can result in lower fuel consumption and greenhouse gas emissions, which

can help to reduce the environmental impact of transportation. Dry ports can help to optimize the use of different transportation modes, such as rail and sea, to reduce the carbon footprint of transportation (Li et al., 2019). By linking inland regions to seaports, dry ports can help to shift more cargo from road to rail or sea, which are generally more energy-efficient and have lower emissions. Dry ports can help to improve the efficiency of supply chains by reducing transportation times, improving inventory management, and reducing the risk of cargo damage (Nguyen et al., 2021). This can help to reduce waste and lower the environmental impact of the supply chain. Many dry ports are implementing sustainable practices such as renewable energy generation, waste reduction, and water conservation. By promoting sustainable practices, dry ports can help to reduce their own environmental impact and encourage sustainable practices throughout the supply chain (Mata-Lima et al., 2019). Dry ports are important for sustainability because they can help to reduce the environmental impact of transportation, improve supply chain efficiency, and promote sustainable practices throughout the supply chain. As the demand for sustainable supply chains continues to grow, dry ports are likely to play an increasingly important role in promoting sustainability in the logistics sector.

Dry ports can play an important role in the agri-food sector by providing a hub for the efficient and timely movement of agricultural products from farms to consumers. Therefore, main research questions (RQ) are: (RQ1) Which are the key ways of using dry ports in the agri-food sector?; (RQ2) What would be potential business models for operating dry ports that can help achieve sustainable agri-food supply chains?; (RQ3) What are the main policy implications of dry ports implementation in the agri-food sector?

In order to address the RQ1 several key ways implying the significance of the dry ports implementation in the agri-food sector are presented. Dry ports provide farmers and food producers with access to international markets by linking them to seaports for export (Wu & Haasis, 2018). This is particularly important for perishable goods that require quick transport to international markets to maintain their quality. Dry ports often include storage and processing facilities, such as refrigerated warehouses and food processing plants (Bask et al., 2014), which can help preserve the quality and freshness of agricultural products during transport. This is especially important for products that require special handling, such as fresh produce and meat. Many dry ports offer value-added services such as packaging, labeling, and quality control (Andersson & Roso, 2015), which can help increase the value of agricultural products and make them more competitive in international markets. By linking inland regions to seaports, dry ports can help reduce transportation costs for agricultural products (Jeevan et al., 2017). This is particularly important for low-margin products such as grains, which need to be transported in large quantities to be economically viable. Overall, the development of dry ports is significant in the agri-food sector because they can help to improve the efficiency and competitiveness of agricultural supply chains, reduce transportation costs, and increase access to international markets.

Some business models for operating dry ports that can help achieve sustainable agri-food supply chains provide answers to the RQ2. Public-Private Partnership (PPP) model implies the collaboration of the government and private sector to develop and operate dry ports (xx). The government provides the land and infrastructure, while the private sector provides the technology and operational expertise. Cooperative model (Gujar & Ng, 2023) implies that farmers and food producers pool their resources to develop and operate dry ports. Public utility model (Chang et al., 2019) implies that dry port is owned and operated by a public utility or local government. Build-Own-Operate-Transfer (BOOT) model (Abdoulkarim et al., 2019) implies that a private sector entity develops and operates the dry port for a fixed period of time before transferring ownership and operational control back to the government. Finally, vertical integration model (Miraj et al., 2021) implies that a food producer or retailer operates its own dry port to support its supply chain operations. Overall, these business models can help to ensure that dry ports are developed and operated with a focus on sustainability, while also leveraging the expertise and resources of the private and public sectors to achieve sustainable agri-food supply chains.

The implementation of dry ports in agri-food supply chains has several policy implications which provide answers to the RQ3. First of them is trade policy which implies that the development of dry ports can facilitate trade between regions and countries, which can help to increase the efficiency and competitiveness of the agri-food sector. Governments may need to develop trade policies that support the development of dry ports, such as reducing trade barriers and tariffs, and promoting international cooperation in the development of supply chain infrastructure. The second one is infrastructure

development. The development of dry ports requires significant investment in infrastructure, including transportation networks, storage facilities, and processing equipment. Governments may need to provide incentives or subsidies to encourage private investment in dry ports, and may also need to invest in public infrastructure to support their development. The third one is regulatory frameworks. Governments may need to develop regulatory frameworks to govern the operation of dry ports in the agri-food sector, including environmental standards, safety regulations, and customs procedures. These regulations should be designed to promote sustainability and efficiency in the supply chain, while also ensuring the safety and security of goods and people. The fourth one is capacity building. The operation of dry ports in the agri-food sector requires a skilled workforce with expertise in logistics, transportation, and supply chain management. Governments may need to invest in education and training programs to build the capacity of the workforce, and may also need to provide incentives to attract and retain skilled workers. Finally, the fifth one is technology development. The operation of dry ports in the agri-food sector requires the use of advanced technology, including logistics software, tracking systems, and automated processing equipment. Governments may need to invest in research and development to support the development and adoption of these technologies, and may also need to provide incentives to encourage private investment in technology development. Generally, the implementation of dry ports in agri-food supply chains has significant policy implications that require coordinated action from governments, the private sector, and other stakeholders to achieve sustainable and efficient supply chains.

Overall, the application of dry ports in the agri-food supply chains can result in significant improvements in efficiency, sustainability, competitiveness, and food safety and quality. Dry ports can help to improve the efficiency of the agri-food supply chain by reducing transit times, improving inventory management, and reducing the need for intermediate handling and storage. Dry ports can help to reduce the carbon footprint of the agri-food supply chain by reducing transportation distances and optimizing the use of transport modes. The implementation of dry ports can help to increase the competitiveness of the agri-food sector by reducing transportation costs, improving access to new markets, and enabling the delivery of higher quality products to customers. Dry ports can help to improve food safety and quality by providing better control over temperature and humidity conditions during transportation and storage. In addition, the use of advanced technologies, such as blockchain and Internet of Things (IoT) sensors, can help to ensure product traceability and reduce the risk of food fraud and contamination.

**Keywords:** dry port; intermodal transport; sustainability; agri-food; supply chain

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