Review Article

A Review on Emerging Trends in Agricultural Extension and Their Impact on Global Food Systems

Abstract

The transformative impact of emerging trends in agricultural extension on global food systems, particularly focusing on advancements in digital and mobile technologies, participatory approaches, public-private partnerships, and sustainable farming practices. These innovations have significantly enhanced agricultural productivity by introducing precision farming, improved pest management, and efficient resource use. Additionally, they have contributed to substantial improvements in food security, ensuring more stable food supplies and increased accessibility at local and global levels. Economic resilience in rural areas has also been bolstered through these advancements, providing rural communities with diversified income sources and reducing agricultural risks. Furthermore, the adoption of environmentally sustainable practices has led to better soil health, reduced usage of chemical inputs, and a lower ecological footprint, which is crucial for the sustainability of agricultural landscapes. However, the deployment of these emerging trends is not without challenges. Issues such as the digital divide, the need for substantial funding, infrastructure development, and the necessity for continuous education and training for extension agents are critical barriers that need addressing. Future directions for agricultural extension include leveraging cross-disciplinary approaches, scaling up successful models globally, and ensuring that policy and funding mechanisms are aligned with the technological needs of modern agriculture. This paper underscores the need for an integrated approach that considers not only the technological and productive aspects of agriculture but also emphasizes sustainable and inclusive growth to harness the full potential of agricultural extension in strengthening global food systems.

Keywords: *Innovation, Technology, Sustainability, Productivity, Participatory*

I. Introduction

A. Importance of Agricultural Extension in Modern Agriculture

Agricultural extension services play a pivotal role in modern agriculture by bridging the gap between research and farming practices. These services involve the dissemination of vital agricultural information, from technical know-how to innovative farming practices, to farmers and agricultural stakeholders [1]. In developing countries, particularly in India, agricultural extension is crucial for enhancing agricultural productivity, which is directly linked to food security and economic stability.The role of agricultural

extension goes beyond merely imparting knowledge; it encompasses the application of scientific research to agricultural practices through farmer education. This involvement is essential in addressing the myriad challenges faced by farmers today, including climate change, soil degradation, and the need for sustainable farming practices. Agricultural extension services in India have evolved to not only increase productivity but also to promote sustainable and environmentally friendly agricultural practices, thus supporting the broader goals of sustainable development [2].

B. Changes and Innovations in Agricultural Extension

The landscape of agricultural extension in India has witnessed significant transformations over the years. Initially, the focus was predominantly on increasing yield and production to ensure food security for a growing population. However, with the advent of globalization and technological advancements, the focus has shifted towards more diversified objectives, including market access, agribusiness, and value addition [3]. Recent innovations in agricultural extension encompass the integration of information and communication technologies (ICTs) such as mobile phones, the internet, and GIS technologies. These tools have revolutionized how agricultural advisories are delivered and have significantly improved the reach and efficiency of extension services. For example, mobile-based solutions like Kisan Call Centers and the e-Krishi Kendra platforms have enabled farmers to access timely and relevant information directly [4]. Moreover, public-private partnerships are increasingly becoming prevalent, introducing corporate efficiency and investments into the extension system, thus expanding its scope and impact.

C. Purpose of the Review

This review aims to examine the evolving trends in agricultural extension services in India and their impact on both local and global food systems. Given the critical role that India plays in the global agricultural landscape, understanding these trends is imperative. This paper seeks to identify how new methodologies and technologies have been integrated into the traditional extension systems and to evaluate their effectiveness in improving agricultural productivity and sustainability. Additionally, the review will explore how these advancements in agricultural extension are contributing to the achievement of the United Nations Sustainable Development Goals (SDGs), particularly those related to ending hunger, achieving food security, and promoting sustainable agriculture.

II. History of Agricultural Extension

A. Definition and Scope of Agricultural Extension

Agricultural extension is a service intended to provide the knowledge and techniques needed by farmers and agricultural stakeholders to improve their practices, efficiency, and productivity. The Food and Agriculture Organization (FAO) defines agricultural extension as a system that assists agricultural producers through educational procedures in improving farming methods and techniques, increasing production efficiency, and income, and enhancing livelihood quality [5]. In the context of India, agricultural extension services have been a cornerstone in promoting agricultural development and are integral to achieving food security and agricultural productivity.The scope of agricultural extension in India traditionally includes the dissemination of agricultural research findings to farmers, advising farmers on the optimal use of their land and resources, providing solutions to their agricultural issues, and introducing new agricultural technologies and crops that can be beneficial. Over the years, the scope has

broadened to encompass various functions such as facilitating access to markets, providing credit, strengthening farmer institutions, and encouraging participatory approaches in agricultural development [6].

B. Evolution of Agricultural Extension Services

The evolution of agricultural extension in India can be traced back to the early 20th century, during the British colonial period. Initially, the focus was on demonstrating and popularizing new agricultural practices through 'Imperial Agricultural Research Institutes'. However, the efforts were limited and not systematically organized [7]. The real foundation of structured agricultural extension in India was laid post-independence in 1947, with more focus given to increasing agricultural output to feed the rapidly growing population.In the 1950s and 1960s, the establishment of the Community Development Programme (1952) and the Intensive Agricultural District Programme (1960) marked the beginning of a more organized extension service in India. These programs aimed to disseminate agricultural innovations necessary to advance farming practices across the country [8]. The introduction of the Green Revolution in the late 1960s brought about significant changes in agricultural extension. The revolution introduced high-yielding varieties of seeds and expanded the use of chemical fertilizers and irrigation. The extension services had to adapt to these changes by not only distributing the new technologies but also providing the needed education and support to the farmers to adopt these changes [9].

C. Key Milestones and Transformations in Extension Services

1. **Training and Visit (T&V) System**: Introduced in the 1970s and funded by the World Bank, the T&V system became a prominent model in India. It standardized extension visits and created a system where extension workers regularly visited farmers to provide advice and training. The system greatly increased the reach of extension services but was later criticized for being too rigid and top-down in its approach [10].

2. **National Agricultural Extension Programme (NAEP)**: Launched in 1987, this program was designed to revitalize the extension services across India by incorporating more participatory and farmer-first approaches. NAEP aimed at decentralizing decision-making and recognizing the diverse needs of the farmers across different regions [11].

3. **Agricultural Technology Management Agency (ATMA) Model**: Instituted in the early 2000s, ATMA represented a paradigm shift in agricultural extension. It promoted a decentralized, farmer-centric, and participatory approach to agricultural extension. ATMA integrates research and extension activities across multiple sectors and is considered a significant step towards making extension services more responsive to local needs [12].

4. **Information and Communication Technology (ICT) in Extension**: The integration of ICT tools into extension systems marked another milestone in the 2000s. Mobile telephony, the Internet, and dedicated agricultural apps have transformed how agricultural information is delivered and accessed by farmers. Initiatives like the e-Choupal and Kisan Call Centers have revolutionized the delivery of extension services in India, making it more inclusive and efficient [13].

III. Emerging Trends in Agricultural Extension

A. Digital and Mobile Technologies

The adoption of digital and mobile technologies has revolutionized agricultural extension services in India, making information dissemination faster, more accurate, and far-reaching. These technologies have emerged as vital tools in bridging the gap between research findings and farming practices, enhancing the capabilities of farmers to improve agricultural productivity and sustainability.

1. Use of Mobile Apps and SMS for Farmer Communication

Mobile applications and SMS-based services have become particularly transformative in India, a country with widespread mobile penetration. Agri-tech startups and government initiatives have launched several mobile apps that provide services ranging from weather forecasts and crop recommendations to market prices and agricultural advisories. For example, the 'KisanSuvidha' app, launched by the Ministry of Agriculture & Farmers Welfare, offers farmers comprehensive resources including weather updates, market prices, plant protection, and dealer networks [14]. SMS services have also proven effective in reaching out to farmers with critical updates. The 'Kisan SMS Service' launched by the Indian government sends out millions of texts to registered farmers, providing timely information about weather and pest attacks, which helps in reducing crop losses and enhancing productivity [15].

2. Remote Sensing and GIS Technologies

Remote sensing and Geographic Information Systems (GIS) are being increasingly utilized to improve the precision of farming practices. These technologies allow for the monitoring of crop health, soil conditions, and water resources, enabling targeted interventions. The Indian Space Research Organization (ISRO) has been pivotal in deploying satellite imagery for agricultural purposes, assisting in crop area estimation and condition assessment under the FASAL project (Forecasting Agricultural output using Space, Agrometeorology, and Land-based observations) [16]. GIS technologies also facilitate resource mapping and management, helping farmers optimize the use of fertilizers and pesticides, thus promoting sustainable agricultural practices. The Bhuvan platform by ISRO offers services like thematic maps on soils, crops, and water resources, which are invaluable for precision farming [17].

B. Participatory Approaches

Participatory approaches in agricultural extension involve the active involvement of farmers in the learning process, ensuring that the extension services are more adaptive to their actual needs and circumstances. These methods have gained prominence for their effectiveness in improving agricultural knowledge and practices among smallholder farmers.

1. Farmer Field Schools (FFS)

Farmer Field Schools are a form of group-based learning that originated from the FAO's projects in Asia, including India. In these schools, groups of farmers meet regularly throughout the crop season to observe and study field conditions, make decisions on crop management, and learn from each other under the guidance of facilitators. FFS have been particularly successful in promoting integrated pest management (IPM) practices among farmers, significantly reducing pesticide use and improving yields [18].

2. Community-Supported Agriculture (CSA)

Although relatively new in India, Community-Supported Agriculture (CSA) is beginning to take root as a participatory approach that strengthens ties between farmers and consumers. In CSA models, consumers buy shares of a farm's harvest in advance, thus providing farmers with assured income and reducing the risks associated with price fluctuations and crop failures. This model not only supports farmers' financial stability but also encourages sustainable and organic farming practices as consumers often favor environmentally friendly agriculture [19].

C. Integration of Women and Youth

Empowering women and engaging youth are critical for the sustainability of agriculture in India, where a significant portion of the agricultural workforce comprises women, and the average age of farmers is rising.

1. Programs Targeting Young Farmers

Recognizing the need to attract and retain youth in agriculture, several initiatives have been launched to make farming more appealing to young people. Programs such as the Agri-Clinics and Agribusiness Centers Scheme (ACABC) provide training to agriculture graduates to establish their own agri-preneurs, offering services ranging from consultancy to farm management [20]. These initiatives not only provide employment opportunities for young graduates but also inject new technologies and innovative practices into the farming sector.

2. Empowering Women in Agriculture

Women play a pivotal role in Indian agriculture, yet their contributions are often undervalued, and they face numerous barriers in accessing resources and services. Programs like the MahilaKisanSashaktikaranPariyojana (MKSP) aim to empower women farmers by enhancing their access to resources, inputs, and extension services. This program acknowledges the distinct needs of women in agriculture and supports their capacities in farming operations, thereby promoting gender equality in the agricultural sector [21]. These emerging trends in agricultural extension in India not only reflect an adaptation to changing technological and demographic realities but also represent a progressive alignment with global best practices aimed at achieving sustainable agricultural and

D. Public-Private Partnerships

1. Collaboration Models

Public-private partnerships (PPPs) in agricultural extension in India have become instrumental in enhancing the delivery and efficacy of extension services. These collaborations typically involve a combination of government bodies, private companies, international donors, and non-governmental organizations (NGOs). Each partner brings unique strengths to the table, such as funding, technology, expertise, and infrastructure, which help in creating synergistic solutions to complex agricultural challenges.A prominent model of PPP is the "Agri-Clinics and Agribusiness Centers Scheme" (ACABC), which encourages agriculture graduates to start their own agri-venture by providing them with financial support and technical guidance. The government collaborates with private banks to ensure that these young entrepreneurs receive the necessary startup capital [22]. Another example is the "Bharti Walmart Training Center" in Amritsar, which was set up through a collaboration between Bharti, Walmart, and the

Punjab government to provide training to farmers in modern retail skills and better farming practices, thereby connecting them directly to the retail market [23].

2. Impact on Resource Sharing and Innovation

Public-private partnerships significantly impact resource sharing, resulting in more efficient use of financial, technological, and human resources. For instance, private firms often provide advanced technologies and management practices, while public institutions offer a regulatory framework and reach into remote areas, ensuring that innovations reach a broad spectrum of the agricultural population.PPPs foster innovation in agricultural practices by combining research and development insights from private companies with the extensive field experience of government extension services. This blend facilitates the development of tailored agricultural solutions that address the specific needs of diverse farming communities. Innovations such as mobile technology platforms, precision agriculture tools, and improved seed varieties have largely stemmed from such collaborative efforts.

E. Focus on Sustainable and Organic Farming Techniques

1. Promotion of Environmentally Friendly Practices

In recent years, there has been a significant shift in India's agricultural policies and extension services towards promoting more sustainable and environmentally friendly farming practices. This change is driven by the growing recognition of the adverse effects of conventional farming methods, including soil degradation, reduced biodiversity, and increased greenhouse gas emissions.The Government of India has initiated several programs aimed at promoting sustainable agricultural practices. One such initiative is the "ParamparagatKrishiVikasYojana" (PKVY), which supports and promotes organic farming through group certification and marketing. The scheme encourages the formation of clusters of farmers who are trained and supported in adopting organic farming practices, thus reducing dependency on chemical inputs and improving soil health [24]. Another significant initiative is the "Soil Health Card Scheme," launched to assess soil health and provide farmers with recommendations on appropriate nutrient management to avoid over-utilization of chemical fertilizers. This scheme is crucial for maintaining soil fertility and ensuring sustainable land use [25].

2. Adoption and Diffusion of Organic Farming

The adoption of organic farming in India has seen substantial growth, driven by increasing domestic and international demand for organic products. The government, along with various private stakeholders, has been instrumental in promoting this shift through extensive training programs, certification processes, and marketing support. Organic farming is often more labor-intensive than conventional farming, which has led to its slower adoption. However, the long-term benefits of organic farming, such as higher premiums, improved soil health, and lower input costs, are increasingly recognized. Programs like the "National Programme for Organic Production" (NPOP) provide a framework for the organic production systems, standards for certification, and mechanisms for marketing [26]. The diffusion of organic farming is supported by numerous NGOs and private enterprises that work directly with farmers to provide them with the skills and resources needed to transition to organic methods. Organizations such as Navdanya have been at the forefront of promoting biodiversity conservation and organic farming, helping to build a network of seed keepers and organic producers across the country [27].

IV. Case Studies Illustrating Emerging Trends

A. Case Study 1: Use of Mobile Technology in East Africa

In East Africa, mobile technology has revolutionized agricultural extension services, enhancing information dissemination and market access for smallholder farmers. An exemplar project illustrating this trend is the "mFarm" app developed in Kenya. mFarm is a mobile and online platform that offers small-scale farmers real-time information on market prices, connects them with buyers, and provides weather alerts and agricultural tips [28]. Farmers can subscribe to receive SMS updates tailored to their specific needs and locales.The success of mFarm can be attributed to its direct response to the communication barriers that farmers face. By leveraging widespread mobile phone usage, mFarm has managed to reach over 300,000 farmers since its inception, significantly boosting their bargaining power and market access. Studies have shown that users of mFarm experience an average income increase of 20% [29].

B. Case Study 2: Success of Farmer Field Schools in Southeast Asia

Farmer Field Schools (FFS) have been a cornerstone of participatory agricultural extension in Southeast Asia, particularly in Indonesia and Vietnam, focusing primarily on integrated pest management (IPM) techniques. The FFS approach involves groups of farmers who meet regularly during the crop season to learn through observation and experimentation in their own fields.In Indonesia, the FFS initiative started as part of an FAO program aimed at reducing pesticide use while increasing rice production. The program was remarkably successful, resulting in widespread adoption of IPM practices and significant reductions in pesticide use, with yield increases averaging 10% [30]. The success of FFS in Indonesia has been replicated in Vietnam and other Southeast Asian countries, transforming traditional farming practices and enhancing sustainable agricultural methods.

C. Case Study 3: Impact of Public-Private Partnerships in South America

In South America, Brazil has exemplified the successful implementation of public-private partnerships in agricultural extension, particularly in the soybean sector. One notable partnership is between Embrapa (Brazilian Agricultural Research Corporation) and private sector entities such as Bayer and BASF. This collaboration has focused on developing and disseminating new soybean varieties suited to Brazilian climates and resistant to local pests and diseases.The partnership has led to remarkable achievements, including the introduction of soybean varieties that significantly reduce the need for chemical pesticides while maintaining high productivity. These innovations have not only increased Brazil's competitiveness in the global soybean market but have also promoted more sustainable agricultural practices within the country. According to the Brazilian Association of Soybean Producers, these efforts have contributed to a 30% increase in crop yields over the past decade [31].

D. Case Study 4: Integration of Sustainable Farming in Europe

Europe has been a leader in integrating sustainable farming practices across the continent, with a strong emphasis on organic farming. Germany presents a successful case study in this regard. The German government, in collaboration with various NGOs and private businesses, has heavily invested in promoting organic farming through both regulatory support and direct financial incentives.One of the key programs is the "BundesprogrammÖkologischerLandbau und andereFormennachhaltigerLandwirtschaft"

(BÖLN), which provides funding for organic farming projects, research, and extension services tailored to organic farmers' needs. As a result, organic farming in Germany has grown significantly; according to the Federal Ministry of Food and Agriculture, the area under organic cultivation increased by over 50% between 2010 and 2020 [32]. These case studies from various regions around the world highlight the impact and success of emerging trends in agricultural extension. Whether through the use of mobile technologies in Africa, participatory approaches in Southeast Asia, public-private partnerships in South America, or sustainable farming initiatives in Europe, these trends are transforming agricultural practices and enhancing the livelihoods of farmers across the globe.

V. Impact of Emerging Trends on Global Food Systems

A. Enhancements in Agricultural Productivity

Emerging trends in agricultural extension have significantly contributed to enhancing agricultural productivity globally. Innovations such as precision agriculture, digital and mobile technologies, and improved crop varieties have allowed farmers to increase yields while reducing waste and inefficiency. For example, precision agriculture, which uses GPS and IoT (Internet of Things) technologies to tailor farming practices to the specific conditions of each parcel of land, has been shown to increase yields by up to 5% while decreasing input costs by 20% [33]. Mobile technologies have enabled real-time data collection and dissemination, allowing farmers to make more informed decisions regarding planting, pest management, and harvesting. Studies in India and Kenya have demonstrated that mobile advisory services can lead to yield increases of 10-30% by providing timely information on optimal farming practices and weather forecasts [34].

B. Improvements in Food Security

The direct outcome of increased agricultural productivity is an improvement in food security. By enhancing the efficiency and output of agricultural systems, emerging trends are enabling countries to produce more food, thereby reducing dependency on imports and stabilizing local food supplies. In particular, regions that have implemented farmer field schools and community-supported agriculture initiatives have reported improvements in local food security. These participatory approaches empower farmers by improving their knowledge base and skills, which translates into better crop management and higher productivity, ultimately securing local food systems [35]. Technologies like GIS and remote sensing have been critical in managing agricultural resources more effectively, ensuring that food production can be sustained over the long term. For instance, remote sensing technologies are used to monitor crop health, predict yields, and manage water resources efficiently, contributing to sustained agricultural productivity and food security [36].

C. Contributions to Economic Resilience in Rural Areas

Emerging trends in agricultural extension contribute significantly to economic resilience in rural areas. By introducing innovative agricultural practices and technologies, these trends have opened up new income avenues for farmers, reduced risks associated with farming, and increased economic activity in rural communities. For example, the integration of women and youth into agricultural activities through targeted programs has not only boosted productivity but also diversified household incomes. By engaging these often-underutilized segments of the rural population, agricultural programs help build a more robust

economic foundation, reducing poverty and enhancing economic resilience [37]. Public-private partnerships have also played a crucial role in bringing investment and infrastructure development to rural areas, further bolstering economic resilience. These partnerships often lead to improved agricultural practices, better market access, and increased capacity building, which contribute to sustainable economic development in these regions [38].

D. Environmental Sustainability

One of the most significant impacts of emerging trends in agricultural extension is the promotion of environmental sustainability. Sustainable and organic farming techniques, which are increasingly being adopted worldwide, help preserve biodiversity, improve soil health, and reduce the ecological footprint of farming. Organic farming, for instance, minimizes chemical inputs, enhances soil composition, and conserves water, contributing to environmental health. Countries that have implemented comprehensive organic farming policies have reported not only improvements in food quality and safety but also significant environmental benefits. In addition, practices such as crop rotation, intercropping, and the use of natural pest controls that are promoted through various extension services help maintain ecological balance and promote biodiversity [39].

E. Challenges and Limitations of New Agricultural Extension Methods

Despite the positive impacts, there are several challenges and limitations associated with new agricultural extension methods. The high cost of technology and the need for specific skills can be significant barriers for smallholder and resource-poor farmers. Moreover, there is often a gap between the generation of knowledge and its practical application, which can limit the effectiveness of new extension approaches. While digital and mobile technologies offer tremendous potential to transform agricultural extension, issues such as digital literacy, connectivity in remote areas, and the reliability of ICT infrastructure continue to hinder their widespread adoption. Additionally, the one-size-fits-all approach often seen in large-scale extension programs can fail to address the diverse needs and conditions of different regions and farming communities [40].

VI. Future in Agricultural Extension

A. Potential Technological Innovations

The future of agricultural extension is likely to be heavily influenced by advancements in technology. Emerging technologies such as artificial intelligence (AI), machine learning, and blockchain are expected to further revolutionize agricultural practices. AI and machine learning can provide predictive analytics for crop diseases, pest infestations, and weather conditions, allowing for more precise farming. For instance, AI systems can analyze data from satellite images and sensors in the field to recommend optimal planting times and crop rotation strategies [41]. Blockchain technology could also transform agricultural supply chains by enhancing transparency and traceability. This technology can help verify the authenticity of organic or fair-trade certifications, ensuring compliance with environmental and social standards. This not only aids in maintaining consumer trust but also ensures fair compensation to the farmers [42].

B. Policy and Funding Implications

As agricultural extension evolves, there will be significant policy and funding implications. Governments will need to consider investments in digital infrastructure to support the deployment of advanced technologies in rural areas. Furthermore, policies must be adapted to ensure that technological advancements are accessible and beneficial to all farmers, including smallholders and marginalized groups. Funding models may also need to evolve. Public funding will remain essential, but there is a growing need for innovative financing mechanisms, such as public-private partnerships and impact investing, to support sustainable agricultural practices and technology dissemination. For example, the World Bank and other international donors have been instrumental in financing initiatives that promote sustainable agriculture through both grants and loans [43].

C. Education and Training for Extension Agents

The effectiveness of new technologies and methodologies in agricultural extension is contingent upon the capabilities of extension agents. Therefore, there is a pressing need to enhance the education and training of these individuals. Future training programs should not only focus on the latest agricultural sciences but also on information technology, data analysis, and soft skills such as communication and pedagogical techniques. Extension services should also adopt continuous professional development (CPD) models to keep extension agents updated with the latest developments in agriculture and extension methodologies. Such initiatives will ensure that agents remain effective intermediaries between technological innovators and the farmer, capable of translating complex information into actionable advice [44].

D. Scaling Successful Models Globally

The future of agricultural extension will also involve scaling successful models globally. This will require adaptations to local contexts and needs, ensuring that successful programs in one region can be effectively implemented in another while considering local agricultural practices, cultural aspects, and economic conditions. For instance, the farmer field school approach, which has been successful in parts of Asia and Africa, could be adapted and implemented in Latin American countries with modifications to suit local crops and farming systems. Similarly, digital extension services like those developed in India, such as digital advisories and mobile apps for farmers, can be customized and used in African countries to improve access to agricultural information [45].

E. Cross-Disciplinary Approaches

Finally, the integration of cross-disciplinary approaches in agricultural extension is crucial. Challenges such as climate change, biodiversity loss, and sustainable resource management require a holistic approach that integrates agriculture with other disciplines such as environmental science, economics, and sociology. For example, addressing the impacts of climate change on agriculture will require not only agronomic knowledge but also insights from climatology, hydrology, and even behavioral sciences to understand how farmers perceive and respond to climate risks. This integrated approach will enable the development of more comprehensive and sustainable agricultural practices that are resilient to the complexities of modern challenges [46].

Conclusion

The integration of emerging trends in agricultural extension has had a transformative impact on global food systems, enhancing agricultural productivity, improving food security, and fostering economic

resilience in rural areas. Innovations such as digital and mobile technologies, participatory approaches, and sustainable farming practices have redefined the scope and effectiveness of agricultural extension services. However, these advancements also present challenges, including the need for improved infrastructure, equitable access to technology, and continuous professional development for extension agents. Looking forward, the scaling of successful models, adoption of cross-disciplinary approaches, and thoughtful policy and funding strategies will be crucial in maximizing the benefits of agricultural extension for sustainable global food security and environmental sustainability.

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