# HOW TECHNOLOGY AND FARMERS' NEEDS SHAPE NEXT-GEN TRACTORS

*by Yatskul A. (Session Rapporteur, France) and Gavioli G. (Session Chairman, Italy)*

## Introduction

Club of Bologna continues to explore and study the various aspects of evolution of agricultural tractors. Giuseppe Gavioli framed the discussion around three converging forces shaping tractor evolution: farmers' needs, creative industrial design, and technological innovation. The session combined analytical insight from FAO, creative vision from CNH Industrial, and a rigorous debate among major manufacturers (AGCO, CNH, John Deere, Kubota) moderated by Prof. Karl-Theodor Renius. Across all contributions, the consensus was clear: the future of tractors will be determined not by technological push but by the capacity to align design, business models, and service ecosystems with the realities of global agriculture.

## 1. Evolving Farmers' Needs as Drivers of Next-Generation Tractor Design in Africa, Asia, and Latin America

*by Houmy K., Kienzle J. (FAO)*

The presentation by Prof. Karim Houmy and Mr. Josef Kienzle of FAO addressed a fundamental issue in the evolution of mechanization: aligning tractor technology with the realities and aspirations of farmers in developing regions. The next generation of tractors must be demand-driven rather than technology-driven, meaning that design, engineering, and business models should follow the genuine needs of smallholders rather than global industrial trends.

### Context and current situation

At the outset, Prof. Houmy recalled that in the 1960s, Sub-Saharan Africa had mechanization levels comparable to Asia, but over subsequent decades tractor density in Africa stagnated while Latin America, the Middle East, and Asia experienced exponential growth. Today, Africa and the Middle East together represent only 3% of the global agricultural machinery market, a figure that reflects decades of underinvestment and limited adaptation of equipment to local conditions.

Typical tractors in these regions are low-powered (below 80 horsepower), rely on diesel engines, and employ manual transmissions with standard hydraulics and PTOs. Safety features such as ROPS and seatbelts are inconsistently installed, and air-conditioned enclosed cabs are confined to large commercial farms. Connectivity remains minimal; GPS and telematics are rarely used outside high-value crops. Maintenance is predominantly local and often improvisational due to scarcity of spare parts and weak service networks, while affordability constraints force many farmers to rely on rental or shared-use models.

### Key drivers of change

The first structural driver identified was fragmentation of farmland. Across Asia and Africa, most holdings consist of multiple small, irregular plots that drastically reduce operational efficiency. Large tractors are impractical in such environments due to high turning radii and transport time losses between fields. Farmers thus need compact, agile, and easily transportable tractors, with modular attachments that can be interchanged rapidly to minimize downtime and maximize field productivity.

Rural-to-urban migration and demographic shifts are intensifying labor shortages, particularly during planting and harvesting seasons. Manual work is becoming uncompetitive as wage costs rise. Farmers therefore require machines that deliver higher throughput with fewer operators, are simple to use, and allow rapid switching between operations. Automation, ergonomic control layouts, and semi-autonomous functions are key enablers to sustain productivity amid declining labor availability.

In many smallholder systems of Asia and Latin America, mixed cropping and crop rotation are common strategies to reduce economic risk and improve soil health. This introduces design complexity: different crops require varying row widths, ground clearance, and tool geometries. The new generation of tractors must therefore feature adjustable chassis, configurable tool spacing, and modular implements adaptable to intercropping and diversified field conditions.

Climatic variability—droughts, floods, and erratic rainfall—combined with soil degradation and erosion, compels a transition toward climate-smart mechanization. Farmers increasingly demand resilient, low-disturbance machinery suitable for conservation agriculture (such as no-till or residue-friendly implements) and a shift to clean propulsion systems, including electric or hybrid drivetrains. A pilot project in Rwanda, developed with Volkswagen, was cited as an early prototype of an e-tractor concept, demonstrating regional interest in sustainable energy solutions.

Affordability remains one of the strongest limiting factors. Tractors involve high upfront costs, while farm incomes are irregular and seasonal. Weak agricultural credit systems and collateral requirements deter lenders. There is the need for innovative financial models—such as leasing, shared ownership, or credit guarantees—to lower entry barriers. The rise of "mechanization-as-a-service" enterprises in several African countries demonstrates a viable alternative to ownership, enabling farmers to access machinery when needed.

The presentation highlighted how poor rural roads, limited repair shops, and unstable energy infrastructure undermine the usability of tractors. The next generation must be robust, field-serviceable, and modular, allowing rapid maintenance even in remote areas. The integration of remote diagnostics and decentralized service networks was proposed as a path to improve uptime and reliability.

Mechanization systems have historically been designed around male operators. Women, who constitute a significant share of the agricultural workforce, face structural disadvantages in terms of access to credit, land, and training. Future tractor design must include ergonomic adaptations for different body types, lighter controls, and gender-sensitive training programs. Inclusive design is not only a matter of equity but also of efficiency, as it expands the user base and improves adoption rates.

Drawing from these drivers, the framework for next-generation tractor design emphasizes compactness, modularity, resilience, and serviceability. Tractors must be easily repairable, even remotely, using integrated diagnostic systems. They should be robust enough to withstand harsh environments, adaptable to conservation agriculture, and designed for clean propulsion through electric or hybrid systems. The principle of "affordability-guided design" underpins this vision, ensuring that innovation translates into practical, accessible tools for smallholders.

Despite clear demand, several barriers persist: limited profitability due to seasonal use, weak policy frameworks, fragmented ecosystems of parts and training, and low awareness among farmers of the benefits of mechanization. The speakers proposed three possible scenarios for the future:

- a baseline of modest growth if current constraints persist;
- an optimistic acceleration of mechanization if enablers—policy, finance, and infrastructure—align; and
- a leapfrogging scenario, where developing regions skip intermediate stages and adopt advanced solutions such as electric, digital, or robotic machinery directly.

FAO views this leapfrog model as realistic, citing analogies with the rapid spread of mobile technologies in rural Africa and Asia.

**Recommendations and conclusion**

The FAO presentation concluded with a call for multi-stakeholder coordination. Designers and engineers must co-develop robust, modular solutions with farmers. Governments should reform import tariffs and standards, while financial institutions and donors must provide risk-mitigation instruments. Service providers are encouraged to expand mechanization-as-a-service networks, and training institutions should strengthen mechanization extension programs to build operator capacity.

The tractors must evolve in response to farmers' real-world needs, integrating technical innovation with social, financial, and institutional change. Compactness, modularity, and resilience are not design preferences—they are prerequisites for inclusive mechanization. With coherent policies and ecosystems, the transition toward affordable, adaptive, and sustainable tractor systems in Africa, Asia, and Latin America is achievable

## 2. Designing Dreams for a Bright Future

*by Wilkie D. (CNH)*

David Wilkie, Head of Industrial Design at CNH Industrial, delivered an engaging and visually rich presentation that explored how creativity, industrial design, and technological innovation converge to define the tractors of the future. With his characteristic mix of realism and artistic imagination, Wilkie invited participants to look beyond engineering constraints and envision tractors not only as tools of production but also as symbols of identity, pride, and aspiration for the modern farmer.

The purpose of design in CNH goes far beyond styling. It is about making machinery more intuitive, safer, and more emotionally engaging. Farmers, he stressed, spend their lives in close contact with their machines; therefore, tractors must evoke confidence, comfort, and even affection. His team's work focuses on visibility, ergonomics, and emotional connection as much as on performance. Design, in his view, must operate as a bridge between technological innovation and human experience, ensuring that new technologies are not merely functional but also accessible and desirable.

Wilkie emphasized that industrial design and engineering must no longer exist as parallel disciplines. Instead, they must operate in continuous dialogue. He called for stronger collaboration between design schools and technology institutions, so that the next generation of designers can integrate digital tools, sustainable materials, and user-centered thinking into the mechanical DNA of tractors.

He then presented a series of collaborative projects with design universities around the world, aimed at redefining how young designers perceive agricultural machinery. Students, accustomed to drawing sports cars and luxury vehicles, were challenged to imagine tractors, harvesters, and agricultural robots. Their naïve and fresh perspective — unburdened by industry conventions — produced designs that were compact, modular, and emotionally expressive. These projects revealed that future designers view farming not as a low-tech occupation but as a field of high creativity and social relevance.

Wilkie shared examples of collaborations with iconic Italian brands such as Lavazza, Ferrero, and Martini & Rossi, where CNH worked with design students to reimagine specialty-crop machinery. In the Lavazza project, students were asked to envision a small-scale, affordable coffee harvester for mountain and hillside farms, where 80% of coffee is still harvested manually. This exercise demonstrated how localized, small-scale mechanization, when designed intelligently, could empower farmers and open new market segments. A similar collaboration with Ferrero focused on hazelnut harvesting.

Returning to CNH's ongoing industrial projects, Wilkie described the evolution of the New Holland design language, centered around a continuous "connected flow line" that runs through the exterior of tractors, combines, and construction equipment. This visual signature, developed through global studio collaboration, reinforces product recognition and conveys unity across platforms.

The final part of Wilkie's presentation explored the human experience of automation and remote operation. Using CNH's latest remote-controlled construction concept as a case study, he described how digital connectivity and autonomy allow operators to work safely from a distance, even in hazardous environments such as earthquake zones. The design introduced the idea of a "control lounge" — a mobile, comfortable workspace that replaces the traditional cab, integrating accessibility for elderly or disabled operators. This reflects CNH's inclusive design ethos, ensuring that new technology widens participation rather than limiting it.

**Manufacturers' Panel Discussion: New Technologie for Tractors: Less Iron and More Intelligence**

**M***oderator Renius K. (Germany), by Pickelmaier B. (AGCO), Zerbino F. (KUBOTA), Nissen H. J. (JOHN DEERE), Fiorati S. (CNH)*

Opening of session by outlining its structure, organized around three main thematic axes: the evolution of standard tractors, the improvement of existing technologies, and the emergence of the fully electric "Generation Two" platforms. He recalled that tractor technology development is influenced by multiple drivers — labor shortages, energy costs, environmental regulation, and digital transformation — and invited the panelists to articulate how their companies balance innovation with customer realities.

The debate unfolded through a sequence of direct questions from the moderator, each addressing a specific frontier of tractor technology.

***Question 1: "Will we see a soon breakthrough of autonomy, or will it remain a niche for standard tractors?"***

Hans J. Nissen from John Deere responded that autonomy is advancing at different speeds depending on geography and crop type. In high-value crop regions, where margins allow faster investment, adoption is accelerating; in broad-acre crops, uptake remains gradual. Nissen noted that labor shortages are a global catalyst, but infrastructure, safety regulation, and financing models determine how quickly autonomy scales. He compared the current stage of autonomous tractor technology to the introduction of GPS-guidance systems twenty years ago, predicting a similar diffusion curve—from large farms with capital capacity to medium and eventually small farms. He also confirmed that, for John Deere, autonomy is not limited to navigation but integrates digital fleet management and implement coordination: "We are no longer selling iron; we are selling full operational ecosystems."

Prof. Renius observed that this paradigm shift from hardware to digital services is economically transformative. Citing data from former Deere leadership, he remarked that the company's profit margins from precision agriculture and automation tools now exceed those from machinery sales. This observation underscored the broader trend toward service-based business models in the tractor industry.

***Question 2: "Have we reached the physical limits of increasing tractor power, or can conventional machines continue to grow?"***

Benedikt Pickelmaier of AGCO responded that, from an engineering standpoint, there is no absolute limit to power scaling, but agronomic and economic constraints are becoming decisive. He explained that while larger tractors reduce operator costs per hectare, the benefits plateau due to soil compaction, logistics inefficiencies, and maintenance complexity. The cost of oversized implements, which increases exponentially with working width, also discourages further upscaling.

B. Pickelmaier referred to field research from AGCO's experimental farms showing that only about 9 percent of soil area remains untrafficked over a cropping cycle. The difference in yield between trafficked and untouched zones can reach one tonne per hectare, proving the negative impact of heavy machinery. He concluded that autonomy and high automation will eventually shift the market from giant tractors toward mid-size autonomous fleets, offering redundancy, agility, and lower compaction risk.

Prof. Renius added that scaling laws in physics work against continuous size increases. Doubling a tractor's length doubles its contact surface but multiplies its weight by eight. This imbalance inevitably worsens subsoil compaction. Therefore, a transition toward optimized, lighter machines — potentially coordinated in fleets — represents both an agronomic and economic imperative.

***Question 3: "How is Kubota approaching maneuverability and turning technologies for small-field applications?"***

Federico Zerbino of **Kubota** reflected on the company's legacy of compact and agile tractors. He recalled that Kubota's *B-speed turn* system, developed in the 1980s, remains effective for Japanese paddy fields, where reducing the turning radius is essential. However, he confirmed that Kubota does not plan to expand this exact solution globally because its design was optimized for small, wet fields with limited traction needs. In Western contexts, overdrive ratios used in B-speed turn systems would be unsafe at higher ground speeds.

Nonetheless, Zerbino indicated that Kubota engineers continue to explore alternative steering and traction solutions adapted to specialty and compact tractors. He noted that the company's design philosophy remains rooted in field-specific optimization, producing different models for Asia, Europe, and North America rather than applying a one-size-fits-all approach.

***Question 4: "What can be done to improve dealer and service networks, especially in relation to customer experience and uptime?"***

Stefano Fiorati from **CNH Industrial** emphasized that customer service has become a central pillar of product strategy. He noted that electrification, automation, and connectivity are creating unprecedented access to operational data, allowing predictive maintenance and remote diagnostics. "Our goal is not only to sell tractors but to guarantee continuous operation."

He explained that real-time data streams enable early detection of component failures, allowing dealers to plan repairs before breakdowns occur. Fiorati mentioned that for tractors in the 200–300 horsepower range, around 80 percent of buyers already choose models with remote service connectivity, reflecting strong acceptance of digital aftersales support.

He also pointed out that service logistics represent a critical cost driver. In some regions, technicians must travel over three hours to reach a customer, resulting in downtime losses. Remote software updates and tele-diagnostics, therefore, serve as both economic and ecological solutions.

***Question 5: "Which fuels will power tractors in 2035?"***

All panelists agreed that there will be no single energy solution. Nissen and Fiorati emphasized that future fuel portfolios will vary by geography and policy environment. In Brazil and parts of Asia, bioethanol and biodiesel will remain dominant, while in Europe and North America, low-carbon drop-in fuels and hybrid systems will coexist with emerging battery-electric and hydrogen options. Zerbino added that even within one country, urban-peripheral farms may adopt electrified solutions earlier than remote ones, where infrastructure constraints persist.

Pickelmaier highlighted that while diesel will remain widespread for at least another decade, its role will evolve toward high-efficiency, hybridized systems, supported by cleaner combustion and digital load management. All participants converged on the expectation that the long-term trajectory favors electrification, especially in smaller tractor classes, with larger units adopting hybrid or alternative fuel systems as energy density improves.

***Question 6: "What is the future of wireless implement control?"***

Responding jointly, Pickelmaier and Nissen discussed the complexities of connectivity between tractors and implements. Pickelmaier explained that AGCO adheres to open standards such as ISOBUS and AEF protocols to guarantee interoperability. He mentioned ongoing research on machine-to-machine networks enabling coordinated field operations, such as harvester-to-grain-cart synchronization.

Nissen, however, expressed caution. He noted that John Deere prioritizes safety and reliability, especially for critical control functions. While wireless data transfer is already used for monitoring and telemetry, Deere does not permit wireless implement control for safety reasons: "A lost signal in a braking or lifting command could cause catastrophic damage." He reaffirmed the company's preference for high-speed wired connections (Ethernet, ISOBUS) in implement control, while leaving wireless links for non-critical data exchange.

Fiorati of CNH agreed, adding that as more data are exchanged between tractors and implements, the industry must prioritize real-time stability and cybersecurity. Wireless communication, while promising, still faces latency and interference challenges that must be resolved before large-scale adoption.

***Question 7: "Are full-electric tractors a viable near-term reality, and what are the critical challenges?"***

The final topic explored the emerging generation of electric tractors. Prof. Renius introduced the question by noting that nearly every major manufacturer has presented at least one electric prototype, but technical and economic viability remain uncertain. He observed that battery volume is approximately 14 times greater than equivalent fuel storage, and energy density remains a limiting factor.

Pickelmaier confirmed that small tractors, particularly in specialty and municipal sectors, are already economically viable as battery-electric units. However, medium and high-power tractors face range and cost barriers. He noted that AGCO's research classifies small electric tractors as 40 percent average load machines, mid-size as 60 percent, and large tractors as 80 percent, highlighting the non-linear scaling penalty of battery systems.

Fiorati added that CNH favors a central-drive electric architecture, which offers advantages for first-generation models. In contrast, front/rear or wheel-by-wheel drives, while technically possible, remain too expensive due to the number of inverters required. He acknowledged that future architecture might evolve toward dual-axle electric drives once motor and inverter costs decline.

All speakers recognized 800 volts as the emerging standard for high-voltage traction systems, ensuring compatibility with the AEF high-voltage implement interface. They agreed that hybrid powertrains and range-extender systems will serve as transitional technologies for mid-size tractors, bridging the gap between diesel and fully electric propulsion.

In conclusion, the panel affirmed that the tractor industry is moving from a paradigm of mechanical optimization toward integrated digital ecosystems, where power, intelligence, and connectivity define competitiveness. The phrase "less iron, more intelligence," as Prof. Renius summarized, encapsulates this transition from heavy metal to smart, adaptive, and sustainable machines.

The discussion revealed strong alignment among manufacturers on key directions — autonomy, electrification, digital service, and data integration — but also healthy divergence in strategies, reflecting the unique strengths and philosophies of each brand. The tone was optimistic yet realistic: the transformation is underway, but success will depend as much on ecosystems, infrastructure, and policy as on engineering ingenuity.