Table S1. Overview of the applications of advanced sensing in scientific studies focused on agroforestry. Abbreviation: A, net photosynthesis; AE, agro-ecosystem; AGB, aboveground biomass; C, carbon; CCC, canopy chlorophyll content; DEMs, Digital Elevation Models; E, transpiration; GHGs, greenhouse gases; GPS: global positioning system; IoT, internet of things; ITCs, individual tree crowns; L, livestock, LAI, leaf area index; LiDAR: light detection and ranging; MODIS: moderate resolution imaging spectroradiometer; N, nitrogen; P, plant; PAR, photosynthetically active radiation: RGB: red-green-blue; S, soil; TDR, Time Domain Reflectometry; UAV: unmanned aerial vehicle.

Components	Approach	Technology	Aim	Reference
AE	AE monitoring	Microclimate monitoring	Build models explaining daily leaf temperatures and wetness duration, and minimum and maximum air temperatures	[133]
AE	AE monitoring	Microclimate monitoring	Effectively monitors microclimate for improved agroforestry management	[45]
AE	AE monitoring	Microclimate monitoring	Evaluation of microclimate effects on yield, quality, and revenue	[46]
AE	AE monitoring	Microclimate monitoring	Measure microclimatic conditions	[63]
AE	AE monitoring	Microclimate monitoring	Accurate detection of temperature increases due to tree loss and land conversion	[134]
AE	AE monitoring	Microclimate monitoring	Improved microclimate and S monitoring, guiding productivity and climate adaptation strategies	[44]
AE	AE monitoring	Microclimate monitoring	Assess the effect of different coffee cultivation systems on water consumption, understand water competition or complementary use between coffee and shade tree species	[49]
AE	AE monitoring	Microclimate monitoring	Assess the effects of different tree species and distances from trees on understory forage nutritive value and productivity, light/shade environment, and microclimate	[135]
AE	AE monitoring	Remote sensing	Characterization of the multiple AE services supplied by an agroforestry system	[37]
AE	AE monitoring	Remote sensing	Accurate and effective characterization of complex agroforestry systems by capturing spatial and ecological diversity	[38]
AE	AE monitoring	Remote sensing	Provided broad-scale aboveground biomass estimates to assess forest recovery	[39]
AE	AE monitoring	Remote sensing	Assessing vegetation recovery, S erosion reduction, water use impacts, and food security trade-offs	[136]
AE	AE monitoring	Remote sensing	Long-term monitoring of land cover change and rainfall variability	[137]
AE	AE monitoring	Remote sensing	Support microclimate improvement and AE recovery in degraded land	[52]
AE	AE monitoring	Remote sensing	Accurate and efficient semantic segmentation of bush vegetation in large-scale agroforestry environments	[71]
AE	AE monitoring	Remote sensing	Accurate, low-cost, and spatially detailed estimation of biomass and C stock in integrated crop–L systems	[138]

AE	AE monitoring	Remote sensing	Accurate mapping and discrimination of agroforestry cocoa from open canopy forest	[40]
AE	AE monitoring	Remote sensing	Quantification of land use and land cover changes, along with household surveys and time-series data	[139]
AE	AE monitoring	Remote sensing	Enable landscape-scale carbon accounting	[41]
AE	AE monitoring	Remote sensing	Improved monitoring and provide guidance for mapping choices	[140]
AE	AE monitoring	Remote sensing	Monitoring of land use land cover changes to support sustainable development, planning, and management	[42]
AE	AE monitoring	Remote sensing	Determination of suitable habitats for critically endangered species	[141]
AE	AE monitoring	Remote sensing	Reduce downstream sediment yields and support gully rehabilitation strategies	[53]
AE	AE monitoring	Remote sensing	Accurate estimation and mapping of AGB and C stocks in the Sudanian Savanna to aid natural resource management	[142]
AE	AE monitoring	Remote sensing	Discriminate landscape characteristics linked to ecosystem services and socio-cultural benefits	[43]
AE	AE monitoring	Remote sensing	Effective tool for evaluating grassland management practices in silvopastoral systems	[143]
L	Health monitoring	Biosensors and accelerometer embedded in eartags; video cameras with automatic movement analysis	Improved disease surveillance with minimal labor and sampling costs	[58]
L	Health monitoring	Camera traps	Modeling the influence of surrounding land-use, habitat characteristics, and presence of other predators to understand honey badger habitat use	[144]
L	Virtual fencing	eShepherd™ (i.e., automated virtual fencing system operating via GPS)	Effective containment without harming cattle welfare	[54]
L	Virtual fencing	Virtual fencing sensors	Improved pasture management efficiency by minimizing labor and maintaining control without physical barriers	[55]
L	Pasture management	Proximal canopy reflectance sensor	Estimation of forage mass, leaf and stem mass, leaf mass, and LAI for pasture management and stocking rate adjustment	[145]
L	Pasture management	Sensors for pasture variables, S moisture, and microclimatic conditions	Understand belowground and aboveground competition	[61]
P	Growth monitoring	UAV-borne RGB and multispectral imagery system	Spatio-temporal analysis of grassland in agroforestry systems at high spatial resolution	[64]

P	Growth monitoring	UAV-borne RGB imagery system	Detect coffee Pations in tropical regions with complex agroforestry systems	[72]
P	Stress detection	portable time domain reflectometer sensor; thermal dissipation probe	Monitoring drought stress in young apple trees in a semiarid agroforestry system	[77]
P	Stress detection	3D ultra sonic anemometers coupled with Campbell 2D sonic anemometers and four temperature and humidity probes	Parameterization of the agroforestry system efficiency to limit spore propagation	[89]
P	Growth monitoring	passive optical sensors (multispectral radiometers on Sentinel-2/MODIS) and active sensors (LiDAR and radar)	Assessment of phenological, morphological and physiological responses of shade-adapted cultivars of winter wheat and barley	[65]
P	Stress detection	S moisture and sap flow sensors	Enabled precise monitoring of tree water use under drought stress	[78]
P	Growth monitoring	Onset HOBO Data Loggers	Measure high-resolution, continuous microclimate data (i.e., temperature and solar radiation) across different elevations and shade conditions	[83]
P	Growth monitoring	LAI sensors and light meters (e.g., ceptometers or quantum sensors)	Detailed description of how spatial configuration modulates inter-specific competition, light availability, and cotton physiological plasticity	[146]
P	Growth monitoring	Mini microclimate sensors and drone-recorded thermal images	Assessment of spatial and temporal microclimate and land surface temperatures variability	[84]
P	Growth monitoring	Heat-pulse sap-flow sensors and S-moisture probes (e.g., TDR or capacitance sensors)	Determine the impact of agroforestry systems on microclimate, yield, and income	[82]
P	Growth monitoring	Moisture sensors (e.g., TDR or capacitance methods) and sap flow sensors (i.e., heat-pulse and thermal-dissipation probes)	Accurate, timely, and spatially detailed estimation of forest aboveground biomass	[81]
P	Growth monitoring	Linear quantum sensors connected to a Campbell CR1000 or Campbell CR1000X datalogger	Monitoring of light availability for pasture growth under tree canopies	[60]
P	Stress detection	Wind speed sensors, uredospore traps	Measure how shade tree traits alter wind flow and spore dispersal	[85]
P	Growth monitoring	UAV-borne multispectral imagery system	Maps crop yield and litter, estimates tree influence distance, and computes Land Equivalent Ratio without needing sole crop data	[74]
P	Stress detection	Air temperature sensor, rainfall gauge, and leaf temperature sensor	Capture key microclimatic factors driving coffee leaf rust development to forecast lesion emergence, sporulation, and infectious area growth	[86]
P	Stress detection	PPFD sensor, air temperature sensor, leaf temperature sensor, S temperature sensor, and relative humidity sensor	Assess microclimate modulation and its impact on crop ecophysiology under different tree genotypes	[80]
P	Growth monitoring	Multi-source and -seasonal satellite imagery	Enables accurate tree species mapping, with improved results using multi-seasonal and dry season data	[147]

P	Growth monitoring	PAR sensor, air temperature sensor	Measured tree effects on light, temperature, and N	[148]
P	Growth monitoring	LiDAR + RGB camera	Accurate 3D semantic mapping in complex field conditions	[70]
P	Growth monitoring	Multitemporal Sentinel-1 (SAR) and Sentinel-2 (optical) satellite data	Accurate mapping of coffee production systems under persistent cloud cover, supporting land-use monitoring and climate adaptation strategies	[149]
P	Growth monitoring	IoT-based tree-ring and diameter sensing system	Real-time, accurate, and affordable measurements of P growth	[90]
P	Plant health	Full-range spectroradiometer; UAV-borne multispectral imagery system	Monitor crop responses to tree shading and stress, supporting precision management	[150]
P	Growth monitoring	High-resolution remote sensing images	Enhanced millet yield prediction, identification of optimal woody cover for crop benefit, and improved understanding of spatial yield drivers	[126]
P	Growth monitoring	PAR sensors, solar radiation sensors, air temperature sensors	Quantification of the effects of *Alnus acuminata* and *Markhamia lutea* trees on maize crops	[151]
P	Growth monitoring	Light sensors	Estimate the daily net photosynthesis and radiation use efficiency of understory wheat leaf	[152]
S	Moisture monitoring	S temperature and S water content sensors	Enhanced agroforestry resilience and informs land use planning in freeze-prone drylands	[48]
S	Moisture monitoring	Electrical Resistivity Tomography	Maps S moisture dynamics	[95]
S	Nutrient sensing	VNIR spectrometer, dry combustion analyzer, andic S property sensors (e.g. for Alp), topographic and vegetation data sources	accurate S organic C prediction and mapping	[105]
S	Moisture monitoring	S moisture sensors, litterbags	Track S moisture and root decay rates	[112]
S	Moisture monitoring, Nutrient sensing	LAI-2000 P canopy analyzer, MODIS satellite, high-resolution satellite imagery (NDVI-based)	Enabled multi-layer LAI mapping, yield prediction, and assessment of AE services like water use and C dynamics	[101]
S	Nutrient sensing	VIS-NIR hyperspectral imager	Accurate, mobile, and cost-effective prediction of S organic C and N	[104]
S	Moisture monitoring	Sap flow sensors and micro-lysimeters	Precise assessment of water use efficiency	[96]
S	Moisture monitoring	Sensors for S moisture, sap flow sensors	Assess the potential of forest-to-silvopasture conversion for mitigating climate change impacts and sustaining hydrologic regulation	[97]
S	Moisture monitoring, Nutrient sensing	Sensors for S moisture, S nutrients and solar radiation	Provide accurate reporting of yield losses in agroforestry systems	[100]
S	GHGs monitoring	Microclimate monitoring	Accurate quantification of greenhouse gas emissions across different agroforestry systems	[50]

S	Nutrient Sensing	X-ray computed micro-tomography	Characterize differences in surface microstructure	[99]
S	GHGs monitoring	Static, vented chambers, sensors for S microclimate monitoring	Quantification of N_2O and CO_2 emissions, S temperature, water content, and surface-S inorganic N	[109]