compost derived from winery wastes has also been shown to enhance physical properties such as soil water-holding capacity and aeration (Cataldo et al., 2021). In semiarid ecosystems, organic management promoted carbon and nitrogen retention within deeper soil macroaggregates and strengthened long-term soil structural integrity, indicating that these structural benefits are not restricted to the surface soil layer (Fracetto et al., 2025). Studies of orchard soils have shown similar trends: organic fertilization reduced soil bulk density, increased porosity and saturated hydraulic conductivity, and increased the proportion of macroaggregates, thereby creating a healthier soil environment for root growth (Su et al., 2026).

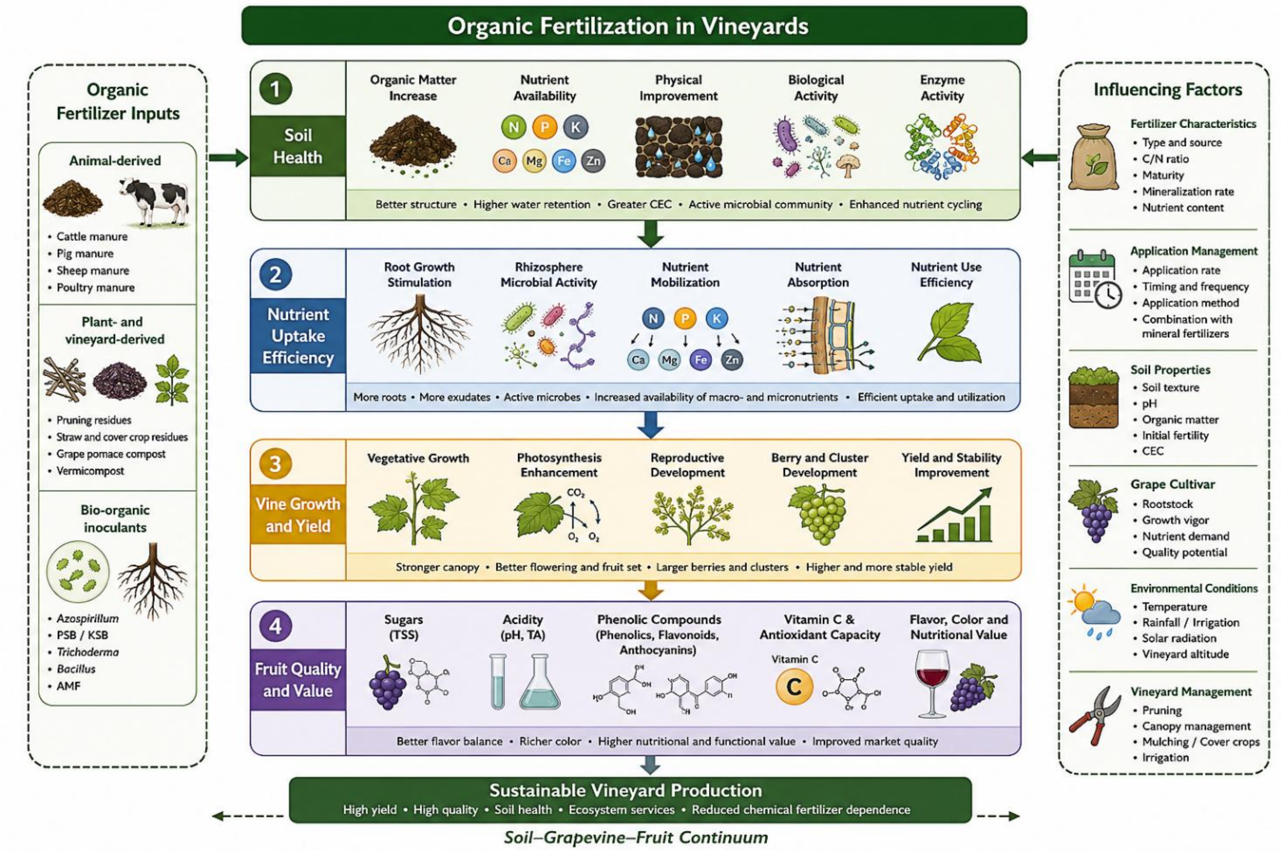

Figure 1 Conceptual framework illustrating the effects of organic fertilization across the soil–grapevine–fruit continuum

Image caption: Organic fertilization improves soil physicochemical properties, microbial activity, and nutrient cycling, thereby promoting root and rhizosphere processes and enhancing nutrient availability, uptake, and utilization efficiency. These improvements subsequently regulate grapevine vegetative growth, reproductive development, yield formation, and berry quality. The magnitude and direction of these effects are jointly influenced by fertilizer characteristics, application management, soil properties, grape cultivar, environmental conditions, and vineyard management practices. Collectively, these interconnected processes contribute to synergistic improvements in vineyard productivity, fruit quality, soil health, and the overall sustainability of grape production

3.2 Regulation of soil chemical fertility

A key chemical effect of organic fertilization in vineyards is the accumulation of soil organic matter and carbon pools. In a terraced Cabernet Sauvignon vineyard, three consecutive years of compost application increased soil organic matter (SOM) content. In Mediterranean and tropical vineyards, organic fertilization also increased total organic carbon and labile carbon and improved the balance between humic and fulvic acid fractions, thereby enhancing soil carbon stability (García-Orenes et al., 2016; Lucchetta et al., 2023; Fracetto et al., 2024). Broader agronomic studies have likewise shown that increases in SOM provide an important foundation for subsequent improvements in soil fertility, aggregate structure, and nutrient-buffering capacity (Xing et al., 2025).

Organic fertilization generally increases nutrient availability, particularly the supply of nitrogen (N), phosphorus (P), and potassium (K), although nutrient release is usually slower than that from mineral fertilizers. In vineyards,