Supplementary material

Table S1. Description of the basic attributes (i.e., indicators) identified by BioDurum_MCA**.** Type include: Fi - indicators working at field level. For these indicators computation is performed in each assessed field and the final outcome is obtained by averaging the results of all fields assuming that the contribution of each field is proportional to its surface; Fa - indicators calculated directly considering all assessed fields or based on general information of a farm. They do not need of any further spatial aggregation.

Type	Basic attribute (measurement unit)	Description	Qualitative classes of sustainability
Fi	Cov (%)	This proxy indicator evaluates the risk of erosion calculating a weighted monthly mean of soil cover percentage considering the whole rotation length. It arises from the combination of two indicators present in the literature in order to consider soil coverage (Vazzana et al., 2012) but giving more weight to the period of greatest risk (October-March) as suggested by Bockstaller et al. (2009). $\mathbf{Cov}(\%) = \sum_{i=1}^{t} m_i w_i / \sum_{i=1}^{t} w_i$ m_i = mean of soil cover percentage during the month i considering all years of the rotation; w_i = weight of month i (from October to March =2; April and September = 1; from May to August = 0.5); t =12	Low: Cov ≤ 30% Medium: 30% < Cov ≤ 35% High: 35% <Cov ≤40% Very High: Cov >40%
Fi	Slp (%)	It considers the slope of the assessed fields as a relevant factor affecting soil erosion.	Low: Slp ≥ 10% Medium: 5% < Slp <10% High: Slp ≤ 5%
Fi	CInp (t C/ha, dry matter)	It computes the mean annual amount of carbon inputs (crop and root residues, green manure, organic fertilisers and amendments) left in field by cropping systems. Crop aboveground residues are calculated from observed crop yields by using harvest indexes reported in Salmoral and Garrido (2015). Crop roots are estimated as 30% of total crop aboveground biomass. Each input i left in soil (C_i) in the year t is also multiplied by its carbon fraction (Fi) and isohumic coefficient (Im_i) using the parameters proposed by Boiffin et al. (1986) $\mathbf{CInp} = \sum_{t=1}^{n} \sum_{i=1}^{m} C_{it} F_{it} Im_{it} / n$ n = number of the assessed years m = number of the inputs	Low: CInp < 0.2 Medium: 0.2 ≤ CInp< 0.25 High: 0.25 ≤ CInp <0.30 Very High: CInp ≥ 0.3
Fa	Till (-)	This indicator considers the most frequently primary tillage type carried out in the farm for seedbed preparation and its effect on soil carbon degradation.	Low: Soil inversion using a mouldboard plough; Medium: Use of tine tools that fracture, but do not invert soil; High: Minimum tillage or strip tillage; Very High: No till
Fi	StrPr (-)	It is a qualitative indicator proposed by Vazzana et al. (2012) in which the user evaluates the structure and the soil physical quality of the fields where each assessed rotation is established	Low: Type 1- Soil with massive or laminar structure. Presence of problems such as water stagnation and soil hard pan; Medium: Type 2- Good soil even if hard in consistency. It can present problems in some areas such as the presence of a moderately developed hard pan; High: Type 3- Soil characterized by a good structure with well distributed pores. It presents no problems.
Fa	MacTraf (-)	The negative effect exerted by the weight of agricultural machinery can be limited thanks to the use of equipment and/or strategies that limit compaction. These strategies can be implemented directly by the farmer or by the contractor to whom the farm turns.	Low: Absence of strategies to limit soil compaction; Medium: The machine transit frequency on the field is reduced by combining multiple operations together or avoiding repeated passes on soil; High: The machine transit frequency on the field is reduced and the load per wheel of the vehicles is kept low by increasing contact surface of the tires and /or decreasing their internal pressure

Fa	StrReg (-)	This indicator evaluates the strategies implemented to regenerate soil structure in particular in the presence of medium (Type 2 - see indicator StrPr) or severe intensity (Type 1) problems. The indicator considers both mechanical (tillage operations) and non-mechanical strategies (i.e., presence of crops with deep root system in the rotation, increase of soil organic matter due to soil amendments and/or cover crops with high C/N ratio) which act on soil structure the former in the short term and the latter in the long term	see Table S2
Fa	Cult (n.)	Number of cultivars over the total number of species present in the assessed rotations (Last et al., 2014)	Low: Cult ≤ 1.2 Medium: 1.2 < Cult ≤1.4 High: Cult > 1.4 or use of Heterogeneous genetic material
Fa	LocCult (n.)	Number of local cultivars in the assessed rotations.	Low: LocCult =0 Medium: 1 ≤ LocCult ≤ 2 High: 2 < LocCult ≤ 3 Very High: LocCult > 3
Fi	Nrot (n.)	Total number of both cash and agro-ecological service crops present in each rotation.	Low: Nrot <3 Medium: 3 ≤Nrot < 4 High: Nrot ≥ 4
Fa	Simp (-)	This indicator is based on the Simpson index (Magurran, 2013) and it assess crop diversity combining species diversity and proportion of each crop along the rotation (DST) and in the space (DSP): **Simp =** 1 - (**DSP**+**DST**)/2 where **DSP =** $\sum_{t=1}^{n}\sum_{i=1}^{c} p_{ti}^{2}$ **; DST=** $\sum_{s=1}^{r}\sum_{i=1}^{c} p_{si}^{2}$ p_{ti} = area covered by crop i in the year t on the total cultivated area (calculated considering all assessed fields and the length of the rotations); p_{si} = area covered by crop i in the rotation of the field s on the total cultivated area; **c**= number of the crops; **r**= number of the fields; **n** = rotation length	Low: Simp≤0.75 Medium: 0.75 <Simp < 0.90 High: Simp ≥ 0.90
Fa	InterCrop (-)	It considers the intercropping strategies implemented in the farm	Low: No intercropping in the farm; Medium: At least a strip-cropping present in a field of the farm; High: At least a relay or a row or a mixed intercropping carried out in a field of the farm
Fi	Leg (%)	It is an indicator proposed by Vazzana et al. (2012). It takes into account the percentage of area covered by legumes (both cash and agro-ecological service crops) on total area covered by all crops in a rotation. The presence of legumes contributes to enhance both temporal and spatial diversification of arable cropping systems influencing the associated diversity of the wild flora and fauna (Köpke and Nemecek 2010, Collette et al., 2011).	Low: Leg ≤ 10% Medium: 10% <Simp≤ 30% High: Simp > 30%
Fa	EFA (%)	Ecological Focus Areas (EFA) were recently introduced as key element in the greening of the Common Agricultural Policy (CAP) of the European Union for improving the ecological conditions and biodiversity of agricultural landscapes. According to CAP, farmers with more than 15 ha of arable area are obliged to implement EFA on 5% of their arable land. This indicator calculates the % of arable land covered by EFA in the farm regardless of the threshold of 15 ha	Low: EFA ≤ 4% Medium: 4%<EFA≤ 5% High: EFA> 5%
Fa	Size (% shortfall)	It is an indicator proposed by Sukkel and Garcia Diaz (2002). It evaluates to what extent the average size of the assessed fields differs from the width considered optimal for improving the ecosystem services through functional biodiversity. Indeed, the field should have a maximum width of 125 m to stay below the range of action of the main terrestrial species of predators. Every 25 deviation units corresponds with a 10% shortfall. Size = $A \cdot (W - 125)/AT$ A = area (m) of fields wider than 125 m; W= average width (m) of the fields wider than 125 m; AT = total area of all assessed fields	Low: Size ≥70 Medium: 25<Size< 70 High: Size≤ 25
Fi	Watvol (m^3/ha)	Mean annual water volume (m^3/ ha) provided to all crops in the rotation	Low: Watvol ≥ 4000; Medium: 1000< Watvol <4000 High: EFA≤ 1000
Fi	WatReuse (-)	It takes into account the water volume (m^3/ ha) coming from wastewater or water harvesting on the total water volume (m^3/ ha) provided to all crops in the rotation	Low: WatReuse <0.2; Medium: 0.2 ≤ WatReuse <0.6 High: WatReuse≥0.6 or rainfed systems
Fi	Microirr (-)	Drip systems are considered more sustainable as they significantly reduce water consumption due to their efficiency. The indicator, proposed by Vazzana et al. (2012), considers the ratio of irrigation volumes managed by drip irrigation on the whole supplied volumes in the rotation.	Low: Microirr <0.2; Medium: 0.2 ≤ Microirr <0.5 High: Microirr ≥0.5 or rainfed systems
Fi	NRisk and PRisk (-)	This indicator considers the risk of nutrient loss (nitrate leaching NRisk and phosphate run-off PRisk) combining the values obtained from two indicators: the nutrient balance (NBal or PBal) and the soil cover percentage (Rcov) during the risk period for nitrate leaching and erosion (months from October to March)	when N/PBal ≤ 1 High when N/PBal > 1 Low: if Rcov≤ 20% Medium: if 20%< Rcov <50%

			High: if Rcov ≥50%
Fi	NBal and PBal (-)	Apparent nutrient balance calculations at rotational level are based on the ratio between nutrient inputs (nitrogen fixation by legumes in cover crops and crop residues, fertilizers and soil amendments) and outputs (crop uptakes) provided to all crops in the rotation. Values used for the computation of N and P concentrations in crop yields and residues are taken from the disciplinary on integrated production of the sicilian region (2018) In NBal, nitrogen fixation in legume is fixed at 70% of the plant needs and considered as input, the other 30% is considered adsorbed by the plant directly from soil. Therefore, only 30% of legume component uptakes are considered as outputs when they are harvested.	NBal Low: Nal < 0.75 or NBal ≥1.25 Medium: 0.75≤ NBal ≤ 0.90 High: 0.9< NBal <1.25 PBal Low: PBal< 0.60 or PBal ≥1.1 Medium: 0.6≤ PBal ≤ 0.80 High: 0.8< PBal <1.1
Fi	NFarm (-)	It calculates the N amount coming from the farm (legume cover crops, on-farm compost, on-farm manure, etc.) on the total N amount that is applied in the rotation	Low: NFarm< 0.30 Medium: 0.30 ≤ NFarm< 0.60 High: NFarm ≥ 0.6
Fi	PReuse(-)	It is a simple qualitative indicator that evaluates phosphorus recycling based on the management of crop residues.	Low: All cash crop residues present in the rotation are removed Medium: Half or more than half of cash crop residues present in the rotation are removed; High: Less than half of cash crop residues present in the rotation are removed Very High: All cash crop residues present in the rotation are left in the field
Fi	PNRw (-)	Phosphorus is a resource subject to depletion. For this reason, this indicator evaluates the amount of phosphorus which comes from non-renewable resources (i.e., phosphorites) on the total P amount supplied in the rotation	Low: PNRw > 0.6 Medium: 0.2< PNRw ≤0.6 High: PNRw ≤0.2
Fa	PrevT (-)	This indicator considers the various preventive techniques adopted by the farm for the prevention of adversities (pests, pathogens, weeds, etc). Weights in relation to the agronomic importance, and values of positive and negative environmental impacts are associated with each preventive technique (see Table S3). The indicator is calculated by making a ratio between the weighted sum of the potential positive impacts on the negative ones.	Very Low: PrevT< 3 Low: 3 ≤ PrevT < 3.5 Medium: 3.5 ≤ PrevT < 4.5 High: PrevT ≥ 4.5
Fa	CurT (-)	It considers the different curative techniques adopted by the farm to limit pests and diseases. The indicator is calculated by making a sum of all negative environmental impacts associated to each technique. A negative impact has always been associated with each technique, assuming that if a curative technique is used, then there is a problem in the assessed farm. The values of the negative impacts are the following: 0.1 vegetable oils; 1 for Neem (*Azadirachta indica*); 0.2 for natural pyrethrum; 0.1 diatomaceous earth; 0.2 iron orthophosphate; 0.4 for copper; 0.3 sulfur; 0.3 for any other plant production product	Low: CurT >0.9 Medium: 0.3 < CurT ≤0.9 High: CurT ≤0.3
Fi	Cu (kg Cu/ha)	This indicator considers the annual mean amount of copper (kg / ha of the active ingredient) used considering the entire rotation.	Low: Cu >2 Medium: 0.5≤ Cu ≤2 High: Cu<0.5
Fi	DiEnC (GJ/ha)	This indicator computes the mean annual direct energy consumption (GJ / ha) derived from the use of fuels in the whole rotation length. Predefined fuel consumption values (L/ha) associated with each crop operation are taken from the tables for fossil fuel subsidies in agriculture approved by Sicilian Region, but they can be easily changed by users	Low: DiEnC ≥ 6.5 Medium: 4≤ DiEnC <6.5 High: 2 ≤ DiEnC <4 Very High: DiEnC < 2
Fi	InDiEnC (GJ/ha)	It computes the mean annual indirect energy consumption (GJ / ha) derived from the use of inputs (fertilizers, plant protection products, seeds, etc.) in the whole rotation length. The following energetic content coefficients are used in the computation: 0.63 MJ/m3 for water (Ozgoz et al., 2017); 0.28 MJ/plant for transplants (Bojaca and Schrevens, 2010); 14.7 MJ/kg for seeds (Baran and Gokdogan, 2014.); 0.26 MJ/kg d.m. for compost (Vazzana et al., 2012); 0.3 MJ/kg d.m. for digestate (Vazzana et al., 2012); 1.91 MJ/kg d.m. for commercial organic fertilizer (Pergola et al., 2018); 1.91 MJ/kg d.m. for commercial organic-mineral fertilizer (Pergola et al., 2018)+12 MJ/kg for P_2O_5; 0.3 MJ/kg d.m. for manure and other organic amendments; 128 MJ/kg for plastic film (Vazzana et al., 2012); 25 MJ/kg for bioplastic film (www.materbiwave.com/dichiarazione.pdf); 7.2 MJ/m for pipe (PVC production = 60 MJ/kg; PVC pipe with a diameter 20 mm and thickness 2 mm = 0.12kg/m); 37 MJ/kg for vegetable oil (Monni and Stirpe, 2010); 3.15 MJ/kg for Neem (Lokesh et al.,2015); 3.15 MJ/kg for natural pyrethrum as Neem; 7.1 MJ/kg for sulfur (Vazzana et al., 2012); 7.1 MJ/kg for diatomaceous earth, and iron orthophosphate as sulfur; 78.2 MJ/kg for copper (Vazzana et al., 2012); 20 MJ/kg for other plant protection products.	Low: InDiEnC ≥ 4 Medium: 3≤ InDiEnC <4 High: 2≤ InDiEnC <3 Very High: InDiEnC < 2

Fa	EnRw (-)	The indicator assesses if farm has plants for the production of energy from renewable sources (hydroelectric, wind, photovoltaic, geothermal and biomass)	Low: No High: Yes
Fi	EnReuse (-)	The indicator calculates the recycled and reused content of non-energy material inputs (on-farm manure, on-farm compost, seeds, crop residues, cover crops, etc.) on the total energy consumption of the assessed cropping system. In the computation, it is used an energetic content of 0.3 MJ/kg d.m. for cover crops and crop residues (Vazzana et al., 2012)	Low: EnReuse < 0.10 Medium: 0.10≤ EnReuse< 0.25 High : EnReuse ≥ 0.25
Fa	CCAd (-)	It counts adding up the strategies implemented by the farmer to adapt to climate change effects. The indicators takes into account the following adaptation strategies: i) use of variety mixtures or evolutionary populations to reduce the variability of production; ii) use of varieties more resistant to drought or with a phenological cycle adapted to new climatic conditions; iii) change of crops in rotation with the introduction of species capable of coping with climate change effects (water scarsity, high temperatures, etc.); iv) introduction of soil moisture conservation techniques (minimize or no tillage); v) use of water harvesting or reuse of waste water; vi) use of micro-irrigation systems to increase the water management efficiency; vii) use of decision support systems or access to advisory services for risk management (drought, floods, pest and diseases)	Low: CCAd ≤ 1 Medium:1<CCAd≤3 High: CCAd > 3
Fa	CCMit (-)	It counts adding up the strategies implemented by the farmer to mitigate climate change effects. The indicator takes into account the following mitigation strategies: i) reduced or no tillage to increase soil carbon sequestration; ii) introduction of cover crops and iii) non-removal of crop residues to increase soil organic matter iv) introduction of legume species in the rotation to increase soil fertility and reduce the amount of external inputs; v) use of energy from renewable sources	Low: CCMit ≤ 1 Medium: 1 < CCMit ≤ 3 High: CCMit >3
Fa	Waste (-)	This indicator counts adding up the following waste management strategies adopted by the farm: i) the production of waste is limited thanks to the re-use of some materials in multiple production cycles (re-use of the same mulch plastic, reuse of the same boxes for multiple transporting movements, etc.); ii) organic residues (e.g. pruning) are reused in the farm through a composting process; iii) the farm has a careful management of the temporary waste storage area where the different types of waste are kept separately to facilitate recycling; iv) the farm has a proper management of the quantities and types of waste stored in the temporary storage, reporting everything in the loading and unloading register; v) the farm is part of an integrated waste organization model based on flows of recyclable waste in a consortium chain system (i.e, partnership between the local authority and the farms for the local processing of green organic waste; partnership between the farm and local recycling industries, etc.)	Low: Waste ≤ 1 Medium: 1 < Waste ≤ 2 High: Waste >3
Fi	EEf (-)	This indicator assesses the economic efficiency of the assessed system considering the ratio between the revenues (€/ha) obtained by the selling of the products (both harvested yields and processed products) on the operating and processing costs (€/ha) for all crops in the rotation.	Low: EEf≤2 Medium: 2<EEf<3 High: EEf≥3 or gross margin (revenues- costs) ≥ 500 €/ha
Fa	WY (-)	$WY = WY_{Farm} / WY_{FADN}$ WY_{Farm} = mean annual yield (kg/ha) of durum wheat obtained by the farm in the assessed years WY_{FADN}= mean annual yield (kg/ ha) of durum wheat (period: 2009 to 2017) reported by Farm Accountancy Data Network (FADN) for the province where the farm is located	Low: WY≤ 0.5 Medium: 0.5<WY< 0.8 High: WY≥ 0.8
Fa	CV (-)	$CV = CV_{Farm} / CV_{FADN}$ CV_{Farm} = coefficient of variation of durum wheat yields obtained by the farm in the assessed years WY_{FADN} = coefficient of variation of durum wheat yields (period: 2009 to 2017) obtained from data reported by Farm Accountancy Data Network (FADN) for the province where the farm is located	Low: CV≥ 1.2 Medium: 0.8<CV< 1.2 High: CV≤ 0.8
Fi	Aid (%)	The indicator evaluates the economic independence of a cropping system considering how much the public aid contributes to its economic result (Craheix et al., 2011). The lower the value of the indicator, the more the system depends on external aid and therefore there is an additional risk associated with the evolution of the public aid regime. Aid = $\sum_{i=1}^{n}[1 - (PAi / GMi)] \times 100$ PA = Public aid (€/ha) received in the year i of the assessed cropping system GMi= Gross (€/ha) = revenues + public aid – costs in the year i of the assessed cropping system n = number of assessed years	Low: Aid ≤ 30% Medium: 30% < Aid ≤ 50% High: Aid > 50%
Fa	SInp (-)	This indicator considers how dependent the farm is on the purchase of durum wheat seeds. It also evaluates (using weights) the different types of procurement considering less impacting the purchase from local seed-producing companies due to the fewer	Low: SInp > 1.2 Medium: 1< SInp ≤ 1.2 High: 0≤ SInp ≤ 1

		energy inputs required for transport and because they are usually able to provide cultivars better adapted to the conditions and needs of the territory. SInp = $\sum_{i=3}^{n} PTi * WTi / \sum_{i=1}^{n} PTi$ PTi = share (%) of durum wheat seed coming from the types of procurement i WTi = weight of the types of procurement i n = types of procurement (identified by a progressive number) Types of procurement and their weights (in brackets): 1. On-farm self-production (1); 2. Seed coming from shares with other organic producers (1); 3. Certified organic commercial locally produced seed (1); 4. Non-organic (derogation) commercial locally produced seed (1.2); 5. Certified organic commercial seed produced in Italy (1.2); 6. Non-organic (derogation) commercial seed produced in Italy (1.5); 7. Certified organic commercial seed produced in foreign countries (1.5); 8. Non-organic (derogation) organic commercial seed produced in foreign countries (1.7)	
Fi	NInp (-)	This indicator considers how dependent the farm is on the purchase of nitrogen fertilizers used in whole rotation in which the durum wheat crop is inserted. The indicator also considers the different types of procurement for the nitrogen fertilizers giving to each of them a weight. NInp = $\sum_{i=2}^{n} PTi * WTi / \sum_{i=1}^{n} PTi$ PTi = share (%) of N fertilizer coming from the types of the procurement i for all crops of the rotation WTi = weight of the types of procurement i n = types of procurement (identified by a progressive number) Types of procurement and their weights (in brackets): 1. On-farm self-production- e.g. manure, compost, green manure, etc. (1); 2. Commercial fertilizer locally produced (1); 3. Commercial fertilizer produced in Italy (1.2); 4. Commercial fertilizer produced in foreign countries (1.5)	Low: NInp > 1.2 Medium: 1< NInp ≤ 1.2 High: 0≤ NInp ≤ 1
Fi	OInp (-)	This is a qualitative indicator that considers the additional costs necessary for the purchase of specific material for crops present in the rotation in which durum wheat is included (Craheix et al., 2011)	Low: It is necessary to purchase specific material or tools which are very expensive Medium: It is necessary to purchase specific material or tools but these are not very expensive High: It is not necessary to purchase any specific material or tools for the crops of the rotation
Fa	Mult (-)	This indicator considers if other income activities (such as educational or recreational activities, bed and breakfast, etc.) are carried out in the farm and their importance for the income. Mult = $\sum_{i=1}^{n} QActi/n$ Act_i = importance of the activity i for the income in function of its contribution to the overall farm income = 2 for very important activity (contribution to the farm income ≥ 20%); 1 for a medium important activity (contribution between 5% and 20%); 0 for not important activity for the farm income (contribution ≤ 5%) n = number of the other income activities present in the farm	Low: Mult = 0 Medium: 0 <Mult ≤ 1 High: Mult > 1
Fa	QTE	This indicator aims to assess the technological quality of durum wheat grains considering how many times in the assessed years the minimum values of some quality parameters have been reached. QTE = $\sum_{y=1}^{m} \sum_{i=1}^{n} Qi/n$ Qi= value for the quality parameter i (1= the minimum required quality has been achieved; 2= minimum required quality has not been achieved) in the year y n = number of qualitative parameters m = number of the assessed years List of the quality parameters and their minimum requirements: i) total impurities (broken seeds, pregerminated seeds, etc.) = maximum 10%; ii) grain test weight= = minimum 76 kg/hl; iii) thousand kernel grain weight= minimum 40g; iv) loss of vitreous aspect=maximum 20%	Low: QTE ≥ 1.75 Medium: 1.25 < QTE < 1.75 High: QTE ≤ 1.25
Fi	QSA (-)	The proposed indicator evaluates the risk of mycotoxin contamination for wheat by taking into consideration the factors that influence fusarium and the accumulation of mycotoxins in the grain such as previous crops, tillage, and sensitivity of cultivars (Craheix et al., 2011) QSA = $\sum_{i=1}^{n} Qi/n$ Qi = contamination risk for wheat i (see Table S4) in the rotation n = number of wheat crops in the rotation	Low: QSA >2.5 Medium: 1.5<QSA ≤ 2.5 High: QSA ≤1.5

Fa	Cert (n.)	The indicator counts the number of quality certifications and labels related to the durum wheat produced in the farm	Low: Cert=0 Medium: Cert=1 High: Cert≥ 2
Fa	NSC	The indicator counts adding up the different strategies implemented by the farm for the sale of its products (sale to large-scale distribution, direct sale, farmer's markets, on-line, etc)	Low: NSC ≤1 Medium: $1<NSC<4$ High: NSC≥4
Fa	TAgr	The sale of products to large-scale distribution (GDO), which can also take place through commercial intermediaries such as cooperatives, or processors, is generally considered an easy solution for farmers. Nevertheless, sales prices are often much lower than those of short supply chains and they are linked to market fluctuations. However, in the case of (total or partial) sale of products to GDO, the type of contract (before or after the harvest) can make the difference.	Low: Sale of products with final destination to GDO predominantly through traditional contracts (after harvest) Medium: Sale of products with final destination to GDO predominantly through protection contracts (before harvest) or through formal supply chain agreements High: No sale of products to GDO but only short chain channels are used
Fa	SCPr (%)	This indicator considers the share (%) of sales of farm products through short supply chain mechanisms (Vazzana et al., 2012)	Low: SCPr ≤ 30% Medium: $30 < SCPr < 50\%$ High: SCPr ≥ 50%
Fa	SCEc (%)	This indicator evaluates how relevant the revenues obtained from the sale of products through short supply chains are compared to those achieved with conventional channels (final destination to large-scale distribution) (Gaviglio et al., 2016) SCEc = [SC/ (SC+LC)]*100 SC = revenues (€) obtained from the sale of products through short supply chains; LC = revenues (€) obtained from the sale of products through long supply chains (final destination to large-scale distribution);	Low: SCEc ≤ 30% Medium: $30 < SCEc < 50\%$ High: SCEc ≥ 50%
Fi	NCD (-)	This indicator evaluates the contribution of the assessed cropping system to the development of new supply chain (Craheix et al., 2011) NCD = $\sum_{i=1}^{n} CONTRi/n$ CONTRi = Contribution value of the cash crop i in the rotation to the development of a new supply chain (1 = crop widely spread in the area and marketed through traditional supply chains; 2 = crop not widespread in the area and / or marketed through of emerging supply chains; 3 = New crop not present in the area which implies the creation of a new supply chain) n = number of cash crops in the rotation	Low: NCD ≤ 1 Medium: $1 < NCD < 1.5$ High: NCD ≥ 1.5
Fi	CEmp (hours/ha)	It assesses the contribution to employment of the assessed cropping system CEmp = $\sum_{i=1}^{n} NHi/n$ NHi= number of working hours per hectare (hours/ha) carried out for the year i n = number of the assessed years	Low: CEmp ≤ 1.5 Medium: $1.5 < CEmp \leq 3.5$ High: $CEmp > 3.5$
Fa	TempW (%)	Temporary employees as percentage (%) of the total number of employees	Low: $TempW > 60\%$ Medium: $40\% < TempW \leq 60\%$ High: TempW ≤ 40%
Fa	SocW (-)	This indicator considers if the farm has activated employment paths aimed at the job placement of disadvantaged and vulnerable groups who are at risk of social exclusion	Low: No High: Yes
Fa	Wsaf (-)	The indicator evaluates the level of workplace safety implemented in the farm through various preventive actions and activities realized to reduce the risks for workers. Wsaf = $\sum_{i=1}^{n} Wi$ Wi = Weight associated to the preventive action i n = number of the preventive actions List of the preventive practices and their weights: 1) Training of employees on safety at work: 1=never, 0= periodic, 0.5=occasional; 2) Has the farm made a risk analysis? 1= no, 0=yes, 0.5 = no, but it will be done in a short term; 3) Farm equipment and machinery (protective structures in case of overturning, seat belts, moving parts protected against accidental contact, etc.) are adequate to the safety standards for workers: 1= no, 0=yes, 0.5 = partially; 4) transformation plants and other farm places have been adapted to the safety regulations for workers (electrical systems, escape routes, fire prevention certificates, signage, etc.)? : 1= no, 0=yes or the farm has no plants; 0.5 = partially; v) the farm has any devices for the protection of workers (gloves, masks, caps, etc.)? 1= no, 0=yes, 0.5= some devices; 5) Have there been any accidents at work in the farm in the last three years? 1= no, 0=yes	Low: Wsaf ≥ 3 Medium: $1.5 < Wsaf < 3$ High: Wsaf ≤ 1.5
Fa	JAct (-)	Does the farm jointly manage income activities with other neighbouring farms such as the direct sale of products, organization of training or recreational activities, etc ?	Low: No High: Yes

Fa	SMac (-)	Does the farm share machinery, equipment or implants with other neighbouring farms?	Low: No High: Yes
Fa	ConP (-)	The indicator considers the different types of associations and consortia in which the farm is involved. Participation in consortia or other forms of association between different companies of a production value chain or the presence of territorial agreements (eg BioDistricts) have the ability to activate the endogenous potential of a territory by creating solid networks of relationships between the actors.	Low: No participation in consortia or other forms of association; Medium: Participation in consortia or other forms of association where only farms are involved (horizontal type); High: Participation in consortia or other forms of association or territorial agreements with the involvement of farms, and different actors of the same production chain
Fa	PrInn (-)	This indicator considers the age and the educational qualifications of the agricultural entrepreneur and his/her employees as the propensity of the farm to innovate. Generally young and educated people are more likely to experiment and adopt more sustainable innovative techniques and processes. PrInn = $\sum_{i=1}^{n} Wi$ Wi = weight associated with the component i for the innovation propensity n = number of the components for the innovation propensity List of the components for the innovation propensity and their weights: i) age of the farmer (1 for > 50 years; 2 for age between 30 and 50; 3 for < 30 years); ii) average age of employees (1 for > 45 years; 2 for age between 30 and 45; 3 for < 30 years); iii) Educational qualification of the farmer (1 for No degree; 2 for degree but not relevant to the work done; 3 for degree relevant to the work done); iv) employees with a degree as percentage (%) of the total number of employees (1 for values ≤ 10%; 2 for values between 10% and 50%; 3 for values ≥ 50%)	Low: PrInn < 6 Medium: 6 ≤PrInn< 10 High: PrInn ≥ 10
Fa	Training (-)	This indicator evaluates the ability of the farmer and employees to enrich and update their knowledge and find the necessary information on specific techniques and innovative strategies to implement in the farm	Low: The entrepreneur and/or his/her employees do not follow any training courses and do not use any other means to find information on specific techniques or on innovative strategies Medium: The entrepreneur and/or his/her employees find the necessary information in specialized magazines, on the internet or through exchanges of knowledges with other farmers or technical staff High: The entrepreneur and/or his/her employees periodically follow specialized training courses
Fa	Mac (-)	The indicator considers how much the farm invests in innovation by evaluating the type and age of their machinery and equipment	Low: Use of traditional agricultural machinery with age > 10 years or outsourcing through contractors Medium: Use of traditional agricultural machinery but with an age <10 years High: Use of modern agricultural machinery assisted by innovative technologies (drones, sensors, etc.)
Fa	Ric (-)	The indicator considers the involvement of the farm by universities or other research centres in research projects and experimental activities	Low: No High: Yes
Fa	Com (-)	This indicator considers all those communication activities (open-day, organization of educational and recreational activities, participation in a network for the exchange of experiences with farmers, communication with consumers, etc.) promoted by the farm for raising awareness of the food products and sustainable production methods among civil society.	Low: No communication activities carried out by the farm Medium: Communication activities occasionally carried out by the farm High: Communication activity regularly carried out by the farm

Fa	LandV (-)	Subjective assessment of the value of the landscape that the farm returns to the society considering: • Elements present in the farm with negative landscape effects (nets, dead trees, abandoned buildings, simplified cropping system, predominance of horizontal elements and linear constructions, monochrome); • Elements present in the farm with positive landscape effects (presence of ditches, walls, hedges, trees, crop diversification, well maintained buildings)	Low: Farm with predominance of negative landscape elements Medium: Farm with a balanced presence of positive and negative landscape elements High: Farm with predominance of positive landscape elements

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Table S2. Qualitative sustainability classes (Low; Medium; High) for the indicator StrPr obtained considering both mechanical (tillage operations) and non-mechanical strategies (i.e., presence of crops with deep root system in the rotation, increase of soil organic matter due to soil amendments and/or cover crops with high C/N ratio) and the type of soil (Type 1: Soil with massive or laminar structure. Presence of problems such as water stagnation and soil hard pan; Type 2: Good soil even if hard in consistency. It can present problems in some areas such as the presence of a moderately developed hard pan; Type 3: Soil characterized by a good structure with well distributed pores. It presents no problems)

Primary tillage operations		**Soil Type 1**		**Soil Type 2**		**Soil Type 3**	
		Use of non-mechanical strategies	No use of non-mechanical strategies	Use of non-mechanical strategies	No use of non-mechanical strategies	Use of non-mechanical strategies	No use of non-mechanical strategies
No till		Medium	Low	High	Low	High	High
Tillage carried out in poor soil conditions (i.e., wet soil)	Tillage operations that partially regenerates the soil structure	Low	Low	Low	Low	Low	Low
	Ploughing or deep tillage that regenerates the soil structure	Low	Low	Low	Low	Low	Low
Tillage carried out in good soil conditions	Tillage operations that partially regenerates the soil structure	High	Medium	High	Medium	High	Medium
	Ploughing or deep tillage that regenerates the soil structure	High	Medium	Medium	Low	Medium	Low

Table S3. Weights, and values of positive and negative environmental impacts (from 0 - no impact to 1 - high impact) associated to each preventive technique used for the computation of the indicator PrevT.

Preventive techniques	**weights**	**positive impacts**	**negative impacts**
Choice of the rotation on the basis of sequences of crops belonging to different families to facilitate the control of the main biotic adversities	2	1	0
Use of resistant or less susceptible crop cultivars to certain adversities	2	1	0
Use of evolutionary populations to select and / or enhance new genotypes that are progressively better adapted to the environment and resistant to pathogens and parasites	1	0.8	0.2 (less control of pathologies that spread via seeds)

Sowing density: low/ medium/high	1	low=0.4
		medium=0.4
		high=0.6
			low=0.6 (potential weed problems);
			medium=0.6 (potential weed problems);
			high=0.4 (potential fungal diseases)

Sowing method: rows / uniform distribution (ud)	1	rows =0.5 ud =1	rows = 0.5 (potential weed problems) ud =0
False sowing	2	0.8	0.2 (disturbance to soil fauna)
Microbial consortia	1	1	0
Intercropping	2	1	0
Cover crops with biocidal action (prevalence of species of the *Brassicaceae* family)	2	0.9	0.1 (disturbance to beneficial flora)
Cover crops with nutritional function (prevalence of species of the *Leguminosae* family)	2	0.9	0.1 (possible nitrogen excesses that can favor diseases)
Cover crops with rapid and vigorous development allowing weed suppression (prevalence of species of the *Graminaceae* family)	2	0.9	0.1 (intermediate hosts of pathogens)
Management of uncultivated areas	2	0.9	0.1 (possible spread of weeds)
Mulch with crop residues	2	0.8	0.2 (if infected, crop residues left in field can promote the spread of some pathologies)
Mulching with biodegradable and compostable plastic films	1	0.6	0.4 (possible increase of pathologies due to higher temperatures)
Solarization	1	0.7	0.3 (soil biodiversity loss)
Flame weeding	1	0.7	0.3 (risk of physiopathies)
Hand weeding	1	1	0
Weed grubbing, grooming	1	0.7	0.3 (disturbance to soil fauna)

Table S4. Contamination risk to fusarium (Qi) for wheat crop (see indicator QSA) based on the previous crop in the rotation, tillage and cultivar sensitivity.

Previous crop	**Tillage**	**Cultivar sensitivity**	**Qi***
Rapeseed, pea, bean, sunflower and other crops	Tillage	Not very sensitive	1
		Moderately sensitive	1
		Very sensitive	2
	No Tillage	Not very sensitive	2
		Moderately sensitive	2
		Very sensitive	2
Straw cereals	Tillage	Not very sensitive	2
		Moderately sensitive	2
		Very sensitive	3
	No Tillage	Not very sensitive	2
		Moderately sensitive	3
		Very sensitive	3
Corn, Sorghum	Tillage	Not very sensitive	2
		Moderately sensitive	2
		Very sensitive	3
	No Tillage	Not very sensitive	3
		Moderately sensitive	4
		Very sensitive	4

*Values taken from Craheix et al., 2011. MASC 2.0, un outil d'évaluation multicritère pour estimer la contribution des systèmes de culture au développement durable. Innov. Agron., 20: 35-48;

Table S5. Results obtained for the basic attributes (i.e., indicators) of BioDurum_MCA for farms F_BP1 and F_BP2 in Basilicata and Puglia regions, and F_SC1 and F_SC2 in Sicily. The abbreviations of the name of the indicators (see Table 2) are given followed by their measurement unit (in brackets).

Basic attributes	**F_BP1**	**F_BP2**	**F_SC1**	**F_SC2**
Cov (%)	36.08	28.47	23.40	36.80

Slp (%)	5	5	3	8
CInp (t C/ha)	0.302	0.076	0.242	0.092
Till (-)	2	4	2	1
StrPr (-)	Type 3	Type 1	Type 3	Type 3
MacTraf (-)	The machine transit frequency on the field is reduced by avoiding repeated passes on soil	Absence of strategies to limit soil compaction	The machine transit frequency on the field is reduced by avoiding repeated passes on soil	The machine transit frequency on the field is reduced by avoiding repeated passes on soil
StrReg (-)	Medium	High	Medium	Low
Cult (n.)	The use of heterogeneous genetic material automatically allows the achievement of High score	1	1	1
LocCult (n.)	0	0	2	0
Nrot (n.)	3.00	3.58	3.00	2.00
Simp (-)	0.86	0.81	0.84	0.63
InterCrop (-)	No intercropping	No intercropping	No intercropping	No intercropping
Leg (%)	61.1	66.7	25.0	50.0
EFA (%)	5	5	5	5
Size (% shortfall)	0.0	28.7	16.0	249.0
Watvol (m^3/ha)	0	0	0	0
WatReuse (-)	0	0	0	0
Microirr (-)	0	0	0	0
Nrisk (-)	Medium (NBal > 1; Rcov=31.67)	High (NBal ≤ 1)	High (NBal ≤ 1)	High (NBal ≤ 1)
PRisk (-)	High (PBal ≤ 1)	High (PBal ≤ 1)	High (PBal ≤ 1)	High (PBal ≤ 1)
NBal (-)	1.08	0.20	0.80	0.05
NFarm (-)	1.00	0.99	0.97	1.00
PBal (-)	0.00	0.01	0.70	0.00
PReuse(-)	Half of cash crop residues present in the rotations are removed	All cash crop residues present in the rotations are left in the field	All cash crop residues present in the rotations are left in the field	Half of cash crop residues present in the rotations are removed
PNRw (-)	0	0	0	0
PrevT (-)	4.56	4.26	3.62	3.62
CurT (-)	0.3	0.0	0.0	0.0
Cu (kg Cu/ha)	0	0	0	0
DiEnC (GJ/ha)	5.55	3.23	5.40	4.05
InDiEnC (GJ/ha)	2.18	2.32	1.99	2.06
EnRw (-)	No	No	No	No
EnReuse (-)	0.40	0.32	0.25	0.22
CCAd (-)	2	3	1	0
CCMit (-)	3	4	2	2
Waste (-)	2	2	3	2
EEf (-)	3.04	1.38	5.34	2.09
WY (-)	0.83	0.38	0.87	0.63
CV (-)	0.25	0.00	0.69	0.84
Aid (%)	49.93	17.94	96.71	71.52
SInp (-)	1.08	0.00	0.68	0.60
NInp (-)	0.00	0.15	0.04	0.00

OInp (-)	It is not necessary to purchase any specific material or tools for the crops of the rotation	It is not necessary to purchase any specific material or tools for the crops of the rotation	It is not necessary to purchase any specific material or tools for the crops of the rotation	It is not necessary to purchase any specific material or tools for the crops of the rotation
Mult (-)	0	0	0	0
QTE	1.0	1.0	1.0	1.0
QSA (-)	1.0	1.0	1.5	1.0
Cert (n.)	0	0	0	0
NSC (n.)	6	3	8	2
Tagr (-)	Sale of products with final destination to GDO predominantly through traditional contracts (after harvest)	Sale of products with final destination to GDO predominantly through traditional contracts (after harvest)	Sale of products with final destination to GDO predominantly through traditional contracts (after harvest)	Even if products derived from the assessed rotation are sold through short supply chain, the farmer also sells products of his farm to GDO through traditional contracts (after harvest)
SCPr (%)	62.58	10.23	27.59	100.00
SCEc (%)	14.89	76.12	88.01	100.00
NCD (-)	1.33	1.00	1.38	1.00
CEmp (hours/ha)	6.21	0.00	1.69	1.08
TempW (%)	0	0	100	0
SocW (-)	Yes	No	No	No
Wsaf (-)	0.50	1.50	0.50	1.50
JAct (-)	No	No	No	No
SMac (-)	No	No	No	No
ConP (-)	No participation in consortia or other forms of association	No participation in consortia or other forms of association	Participation in consortia or other forms of association where only farms are involved (horizontal type)	No participation in consortia or other forms of association
PrInn (-)	6.0	8.0	6.0	6.0
Training (-)	The entrepreneur periodically attends specialized training courses	The entrepreneur find the necessary information in specialized magazines, on the internet or through exchanges of knowledges with other farmers or technical staff	The entrepreneur periodically attends specialized training courses	The entrepreneur find the necessary information in specialized magazines, on the internet or through exchanges of knowledges with other farmers or technical staff
Mac (-)	Use of traditional agricultural machinery but with an age <10 years	Outsourcing through contractors	Use of traditional agricultural machinery with age > 10 years	Use of traditional agricultural machinery with age > 10 years
Ric (-)	Yes	Yes	Yes	Yes
Com (-)	Communication activities occasionally carried out by the farm	Communication activities occasionally carried out by the farm	Communication activity regularly carried out by the farm	No communication activities carried out by the farm
LandV (-)	Farm with a balanced presence of positive and negative landscape elements	Farm with a balanced presence of positive and negative landscape elements	Farm with a balanced presence of positive and negative landscape elements	Farm with a balanced presence of positive and negative landscape elements