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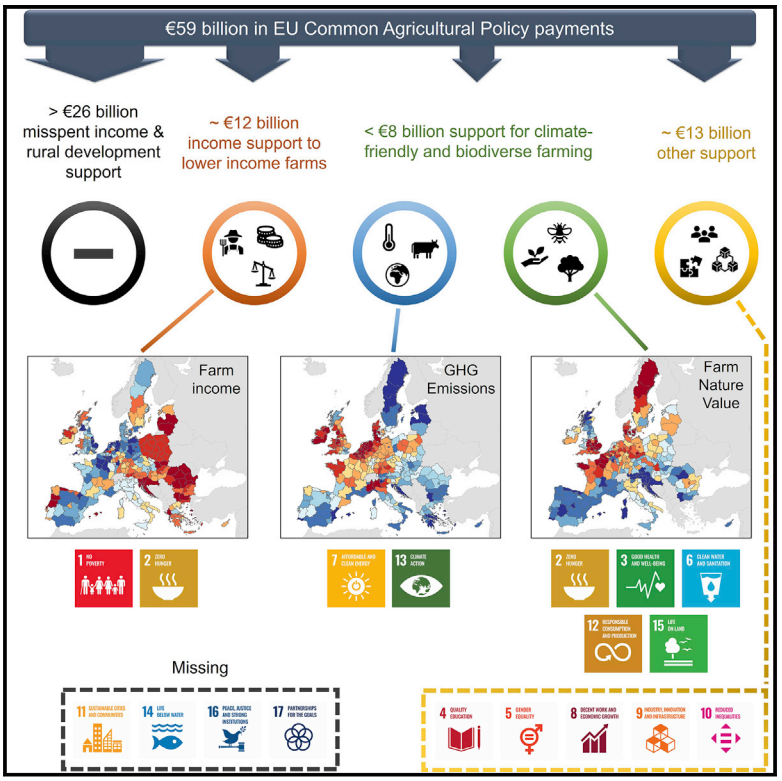
Billions in Misspent EU Agricultural Subsidies Could Support the Sustainable Development Goals

Graphical Abstract



Highlights

- Prudent EU agricultural policy reform could greatly benefit sustainability
- EU agricultural subsidies currently not being spent where they are most needed
- More support for environment- and climate-friendly practices is required
- Result-based payments and better monitoring of outcomes is necessary

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In Brief

The EU's 2021–2027 Common Agricultural Policy (CAP) has great potential to contribute to sustainable development, but changes are required to unlock this potential. Currently, vast CAP spending is not going where it is most needed, and more support for environment- and climate-friendly practices is required. Redistributing income support from already profitable farming regions to other goals of the CAP could unlock some of the policy's untapped potential. Result-based payments and better monitoring and evaluation are also necessary.

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Article

Billions in Misspent EU Agricultural Subsidies Could Support the Sustainable Development Goals

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SCIENCE FOR SOCIETY Global agricultural subsidies total over $700 billion per year but often drive environmental damage and fail to provide broader social benefits beyond farming. In the EU, around €54 billion per year of public funds have been spent under the Common Agricultural Policy (CAP) since 2006. The CAP will be reformed after 2020, and we reveal the untapped potential for vast spending under the policy to contribute to sustainable agriculture in Europe. To do so, CAP payments will need to be redistributed from supporting income in regions where farming is already profitable to supporting farmers to implement environment- and climate-friendly practices. Member States will also need to play a role in monitoring and evaluating whether CAP spending is actually achieving the desired outcomes, using result-based payments and a better set of monitoring indicators. Our results can help researchers, NGOs, and citizens to participate in the CAP reform debate so that public spending provides public goods.

SUMMARY

The Common Agricultural Policy (CAP) is the guiding policy for agriculture and the largest single budget item in the European Union (EU). Agriculture is essential to meet the Sustainable Development Goals (SDGs), but the CAP's contribution to do so is uncertain. We analyzed the distribution of €59.4 billion of 2015 CAP payments and show that current CAP spending exacerbates income inequality within agriculture, while little funding supports climate-friendly and biodiverse farming regions. More than €24 billion of 2015 CAP direct payments went to regions where average farm incomes are already above the EU median income. A further €2.5 billion in rural development payments went to primarily urban areas. Effective monitoring indicators are also missing. We recommend redirecting and better monitoring CAP payments toward achieving the environmental, sustainability, and rural development goals stated in the CAP's new objectives, which would support the SDGs, the European Green Deal, and green COVID-19 recovery.

INTRODUCTION

Transforming agriculture to support both human and environmental health is recognized as critical to achieving the shared international agenda for social development and environmental protection[1] found in the United Nations' Sustainable Development Goals (SDGs).[2] Agriculture is crucial to providing good nutrition for human health, but the driving role of agriculture for biodiversity loss, water use and pollution, air pollution, and climate change must also be addressed.[3–5] European agriculture is a key case study to this end because the European Union (EU) is committed to being a world leader in achieving the SDGs.[6] Furthermore, the European Commission has presented its European Green Deal[7], which is "an integral part of this Commission's strategy to implement the United Nation's 2030 Agenda and the sustainable development goals" (p. 3). The Green Deal recognizes the importance of a fair, healthy, and environmentally friendly food system in its "Farm to Fork" strategy, and claims at least 40% of the CAP budget for 2021–2027 would contribute to climate action. The Green Deal also recognizes that the EU is not meeting its objective to halt biodiversity loss, mainly driven by unsustainable land use.

Achieving the SDGs will require aligning food production with environmental, societal, and rural development goals. In light of the urgent need to reconcile food production with sustainable development and make effective use of limited public funds, agricultural subsidies that support overproduction of unhealthy foods in environmentally damaging ways are coming under increasing scrutiny. A new report[8] finds global agricultural subsidies total over $700 billion (~€640 billion) per year, with many driving unsustainable production practices and environmental damage. If applied more prudently, such subsidies could be a powerful tool to leverage agriculture's contribution to achieving the SDGs.

The Common Agricultural Policy (CAP) is the guiding agricultural policy of the EU, and the European Commission has communicated that the future CAP (i.e., after 2020) should evolve in line with the SDGs.[9] CAP spending has averaged €54 billion annually from the EU budget since 2006[10] (although annual spending varies and Member State spending is additional), totaling €362.8 billion of public spending from 2014 to 2020 and constituting 38% of the EU's budget for that period.[11] However, at the national level, payments are concentrated among a few recipients[12], and only ~4% of the CAP budget goes to financing dedicated agri-environment-climate measures.[13]

The CAP was founded in 1962 with the original goals to increase agricultural productivity, ensure a fair standard of living for the agricultural community, and ensure market stability, as established in the Treaty on the Functioning of the European Union. Its original focus has been expanded over the decades from being farmer-, production-, and consumer-orientated to nine modern objectives encompassing a broad range of societal concerns, proposed in 2018 to[14]

(a) support viable farm income and resilience;
(b) enhance market orientation and increase competitiveness;
(c) improve farmers' position in the value chain;
(d) contribute to climate change mitigation and adaptation;
(e) foster sustainable and efficient management of natural resources;
(f) protect biodiversity, enhance ecosystem services, and preserve habitats and landscapes;
(g) attract young farmers and facilitate rural business development;
(h) promote employment, growth, social inclusion, and local development in rural areas;
(i) respond to societal demands on food and health quality, and animal welfare.

However, the original objectives are still in place, and the two sets of objectives are in stark contrast to each other.[15]

Currently, the CAP is organized under two "pillars," where *Pillar I* contains market management (5% of CAP budget) and direct payments to farmers (72% of CAP budget), and *Pillar II* contains schemes related to rural development, the environment, and climate action (23% of CAP budget) (from here on italicized terms in the text are defined in Table 1).

The CAP has a decades-long history of reform successively aiming to address overproduction, inequality, and environmental concerns with the structure of payments (Note S1). In its first three decades, CAP support to farmers through guaranteed minimum prices for products ultimately resulted in extreme levels of overproduction described as "lakes of milk and beef mountains"[16] in the 1970s and 1980s. To address this problem, the MacSharry reform in 1992 replaced market support with so-called *direct payments* to farmers, which were coupled to production based on areas of eligible crops and numbers of eligible livestock. However, *coupled direct payments* did not sufficiently reduce production surpluses, which led to the reforms in 2003 (called the Mid-Term Review) cutting the link between direct payments and production.[17] Since 2005, farmers receive the majority of their support as *decoupled direct payments* based on their agricultural area. This area-based support is contingent on farmers keeping their land in "*good agricultural and environmental condition*" and complying with *Statutory Management Requirements* including meeting minimum standards for protection of the environment, animal health and welfare, and food safety (Table 1). Three remaining problems with direct payments after the 2003 reforms, however, were that (1) rates of decoupled payments varied substantially both within and among the Member States,[18] (2) payments were concentrated among few farmers, and (3) the CAP still failed to adequately address citizens' concerns regarding the sustainability of farming, the environment, and climate change.[19] Reforms undertaken to date to address each of these problems have so far proven ineffective, despite the introduction of *internal* and *external convergence*, *capping* and *redistribution* of payments, and *green direct payments* (Table 1 and Note S1).

If direct payments contributed to improving income distribution and achieving the SDGs (beyond what would be achieved through market forces alone), then they could be said to be increasing societal welfare. Otherwise these payments could be better used in the pursuit of other goals by providing the necessary support to farm systems that provide public goods in the form of rural, cultural, and environmental benefits that are not sufficiently rewarded on the market, such as in marginal and low-income areas characterized by climate-friendly agriculture and extensively managed grasslands with high biodiversity and social and cultural values.[20] The CAP is currently undergoing reform, with a new policy being proposed for 2021–2027,[14] so analysis of its contribution to multiple social and environmental goals is timely.

Here, we analyze the potential for CAP spending to contribute to achieving its nine modern objectives (as listed in the Commission's June 2018 proposal[14]) and the SDGs in rural Europe. We first expand on recent evaluations of the CAP and SDGs based on expert judgment[15] by quantifying the alignment between CAP payment instruments (referred to in EU legislation as measures), its modern objectives, the SDGs, and CAP monitoring and evaluation indicators. We then scrutinize the distribution of recent CAP payments against social and environmental needs and the provision of public goods through CAP spending. We utilize public data from each Member State centered around 2015 (curated by farmsubsidy.org), which we made spatially explicit and translated to align measures among Member States, to track every CAP payment made by location and measure,[21] revealing that CAP spending is not distributed where farmers' income needs are greatest or where farming is contributing to environmental and climate objectives. We argue that this imbalance

Table 1. Key Concepts in the Design and Implementation of the Common Agricultural Policy (CAP) of the European Union

CAP Term	Definition
Pillar I of the CAP, also called European Agricultural Guarantee Fund (EAGF)	The main division of accounting for 77% of the CAP budget where 72% constitutes *direct payments* to farmers conditioned on them achieving *cross-compliance*, and 5% market management activities (interventions). Since 2005, these payments are based on farmland area per se to remove the incentive to overproduce. Payments are administered by Member States' national governments
Pillar II of the CAP, also called European Agricultural Fund for Rural Development (EAFRD)	The smaller division of accounting for 23% of the CAP budget, which relates to rural development measures, and voluntary measures that are beneficial for the environment and address climate change. These payments generally require national government co-financing of 50%
Direct payment	As a consequence of the MacSharry reform in 1992, the EU began replacing price support (i.e., guaranteed minimum prices for major products) with payments made directly to farmers. This was initially done using *coupled direct payments*, which were replaced in 2005 by *decoupled direct payments*
Coupled direct payment	Direct payments made to farmers from 1992 to 2004 were based on the areas of eligible crops and numbers of eligible livestock, meaning that farmers were required to produce commodities to be eligible for payments, and hence incentivized to overproduce
Decoupled direct payment	As a consequence of the Mid-Term Review or 2003 reform, farmers are no longer required to produce commodities to receive the majority of direct payments. Instead, these are based on their agricultural area (farm size), given that they satisfy the *cross-compliance* conditions
Good Agricultural and Environmental Condition (GAEC)	Land maintenance conditions applying since 2005 for farmers to receive *decoupled direct payments*, such as keeping their agricultural land free of trees and bushes, where agricultural production of fodder or food crops automatically qualifies
Statutory Management Requirements (SMR)	National and EU regulations relating to public, animal, and plant health; animal welfare; and the environment that must be followed by all farmers, whether they receive CAP support or not. For example, this includes following rules set out in EU regulations on pesticides, the Nitrates Directive, and Natura 2000
Cross-compliance	Mandatory conditions that must be met before a farmer receives any *decoupled direct payments*. These include both complying with regulations related to agriculture (see *SMR*) as well as land maintenance requirements (see *GAEC*)
Internal convergence (internal equalization)	The mandatory CAP mechanism for equalizing *decoupled direct payments* to a uniform hectare payment within each Member State. The need for this mechanism emerged due to substantial variation in the hectare payment rates among farms following the introduction of *decoupled direct payments* in 2005, when many Member States elected to convert portions of previous livestock payments to farm-specific decoupled area payments. Even farms that ceased livestock production after 2005 retained the right to their farm-specific payments
External convergence (external equalization)	The mandatory CAP policy of equalizing *decoupled direct payments* to a uniform payment per hectare throughout the EU. Large variations in payment rates have emerged among Member States because *direct payments* introduced with the 1992 reform were derived from historical support levels based on price support, and payment rates for states joining the EU after 2005 (i.e., former Eastern bloc countries) were set substantially lower than in existing Member States
Voluntary coupled support (VCS)	*Coupled direct payments* re-introduced in the 2013 reform. These payments coupled to particular products aim "to secure the future of potentially vulnerable sectors," but are limited to at most 13% of each states' direct payments national budget (envelope)
Capping	A mechanism by which Member States can reduce or cap (set an upper limit on) payments to large farms (currently applicable to farms receiving over €100,000 in annual Pillar I payments)
Redistribution	A mechanism by which Member States can increase or redistribute payments to small and medium-sized farms
Green direct payment	As a part of the 2013 reform, 30% of *decoupled direct payments* were conditioned on farmers meeting particular environmental obligations through fulfilling two "greening" measures (see *EFA* and *Crop diversification*)
Basic Payment Scheme (BPS)	The name of the instrument for making *decoupled direct payments* to farmers from 2015 (replacing the Single Payment Scheme or SPS)

(*Continued on next page*)

Table 1. *Continued*

CAP Term	Definition
Crop diversification	One of two conditions that individual farms must meet before receiving *green direct payments*. It requires farms to grow a minimum of three crops on their arable land, while no single crop may cover more than 75% of the farm's area, and any two crops not more than 95% of the area. It aims to avoid monocultures and thereby improve soil health
Ecological Focus Areas (EFA)	One of two conditions that individual farms must meet before receiving *green direct payments*. It requires farms to manage at least 5% of their arable land as semi-natural habitat, primarily to safeguard and improve biodiversity on farms
Conditionality	Proposed reform post 2020 whereby requirements for *cross-compliance*, *EFA*, and *crop diversification* are jointly administered and all must be met before receiving basic payments
Eco-schemes	Environmental initiative for post 2020 whereby the Commission has made it mandatory for Member States to offer their farmers more flexible Pillar II-type agri-environment and climate measures as part of Pillar I. Member States may reallocate up to 20% of Pillar II payments for this purpose. Farmer schemes must be voluntary
Agri-environment-climate measures (AECM)	Agri-environment and climate measures financed under Pillar II (previously called agri-environmental schemes or AES). These include measures to, e.g., preserve permanent grasslands, promote organic agriculture, and reduce nutrient emissions from farmland to water
National strategic plans	Requirement for post 2020 whereby Member States must detail to the Commission how they will use both Pillar I and Pillar II funding in a single implementation plan or program, as opposed to separately as previously. The intention is to increase synergies between income support and rural development goals

Terms are listed as mentioned chronologically in the text and in Note S1.

limits the CAP's potential contribution to achieving its own objectives as well as the SDGs as claimed by the Commission. We suggest equitability (i.e., needs-based income support) is essential for the future CAP to achieve its modern objectives and contribute to the SDGs, as are payments targeted toward the objectives using clearly aligned instruments (measures) and monitored with supporting impact indicators.

RESULTS

Alignment of CAP with the SDGs

We find that many connections between the CAP and the SDGs exist, but their full potential is currently limited because of the inequitable distribution of CAP spending among its objectives. More than 60% of the current CAP budget goes to supporting only one of the CAP objectives[15]—viable farm income (objective (a)), which aligns with targets for only two of the 17 SDGs (building resilience of the vulnerable [SDG1] and increasing incomes of small-scale food producers [SDG2]) (Figure 1). Meanwhile, several other CAP objectives have the potential to contribute to many social and environmental SDGs but receive little funding to do so. These objectives with high potential for the SDGs are supported almost exclusively by the smaller Pillar II funding and include environmental care (e), 2% of CAP budget; preserving landscapes and biodiversity (f), 9%; generational renewal (g), less than 1%; vibrant rural areas (h), 6%; and protecting food and health quality (i), 2% (Figure 1).

In addition, there is currently low ability to monitor how the CAP contributes to the SDGs, because appropriate indicators aligned with the SDGs are insufficient (Figure 1), which limits follow-up and review of the policy. The most relevant set of CAP indicators for the SDGs are the Target indicators, where nearly all can be linked with SDGs, but the majority of indicators do not align with any SDGs (gray box "not aligned" in Figure 1); this makes it difficult to monitor and evaluate progress or policy contributions toward desired social or environmental goals (see also Scown and Nicholas[23]). The two SDGs most strongly aligned with the CAP objectives (work and economy [SDG8] and life on land [SDG15]) have few indicators for monitoring under the CAP, so it will be difficult to monitor their effectiveness without additional indicators. Three more SDGs well aligned with CAP objectives have only a few indicators (poverty [SDG1], inequality [SDG10], and sustainable consumption and production [SDG12]) (Figure 1; Supplemental Experimental Procedures and Table S1). For two SDGs aligned with the CAP objectives, there are no CAP indicators to evaluate progress toward these goals (health [SDG3] and gender equality [SDG5]), while two SDGs are missing entirely from the CAP objectives (oceans [SDG14] and good governance [SDG16]) (Figure 1).

CAP Payments Compared with Social and Environmental Needs

Our results show that CAP area-based decoupled direct payments are not well aligned with the goal of supporting fair farm incomes (CAP objective (a) and linked to SDGs 1 and 2). Member State median net (i.e., disposable) incomes ranged from €4,357 in Romania to €29,285 in Luxembourg in 2015, compared with the 2015 EU median of €16,163 (all national incomes adjusted to purchasing power standard [PPS] to reflect equal ability to buy goods and services in different countries). We found average farm incomes in 65% of regions are at or above the 2015 EU median, but most agricultural jobs are in the lowest-paid regions (Figure 2A). The equivalent of more than 5.5 million full-time farm employees (orange crosses in Figure 2A)—over half of the

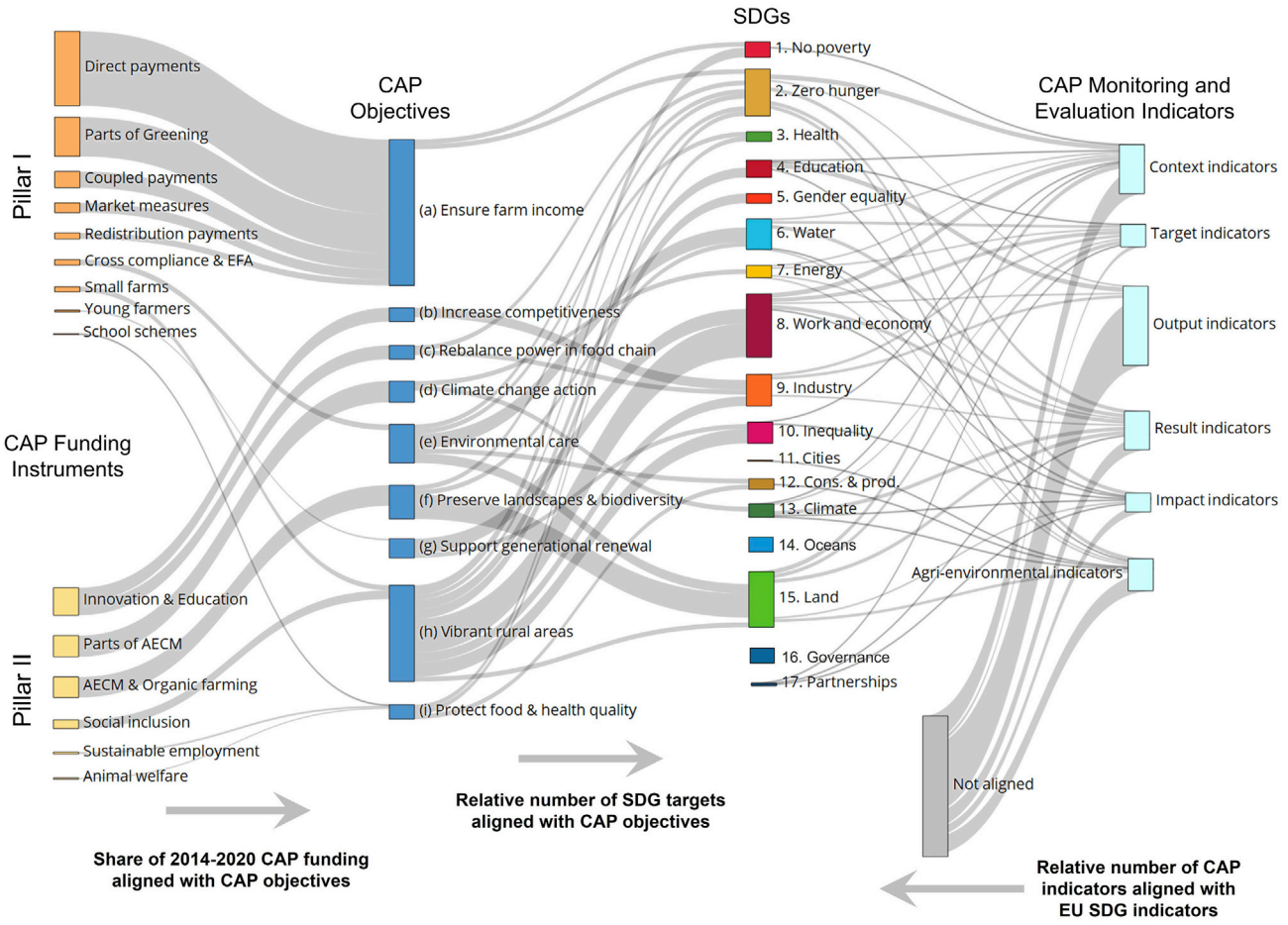

Figure 1. Alignment of CAP Budget, Objectives, SDGs, and CAP Monitoring Indicators

Box height for CAP funding instruments reflects the share of the 2014–2020 CAP budget. Box height for CAP objectives reflects the proportion of funding support each objective receives or the number of SDG targets each objective aligns with, whichever is greater. Box height for SDGs reflects the number of targets that align with CAP objectives plus the number of CAP indicators that monitor progress toward each goal. Box size for CAP indicators reflects the number of indicators in each set. Data sources: current CAP funding instruments (€) and contribution to achieving CAP objectives (Pe'er et al.[15,22]); CAP objectives linked to SDG targets based on their official wording (see Experimental Procedures, Supplemental Experimental Procedures, and Table S1); SDGs linked with observable indicators used to monitor and evaluate the CAP based on the analysis of Scown and Nicholas.[23] Note: analysis of Pe'er et al. is based on the 2014–2020 CAP budget.

EU's full-time farm labor—work in the lowest-paid 20% of regions grouped by average farm-labor income (Figure 2A). Meanwhile, the regions with the highest farm incomes support the fewest jobs, with more than ten times more farm jobs located in the lowest compared with the highest income deciles (Figure 2A).

According to our analysis, richer farming regions receive substantial CAP payments that bring them further above the EU median income, on average, while CAP payments to the poorest 40% of regions are not sufficient to make farm income reach the EU median disposable income. CAP income support payments add only €1,200 per year to the average income of farmers in the lowest-income 10% of regions (where average annual agricultural factor income is €5,900), which are mostly in Eastern Europe and parts of Spain and Portugal (Figure 2B). In contrast, average farm incomes in the top 40% of regions are already well above the EU median, yet income support payments average an additional €6,000–€11,900 per full-time worker in these regions (Figure 2A). Even without any CAP income support, average farm incomes in the top 70% of regions would already be close to or above the EU median (Figure 2A). Thus, current payments increase income inequality within agriculture (exacerbating income differences between rich and poor farmers), so the necessity of income support in farming regions already above the EU median income across sectors must be questioned.

In terms of farming providing benefits related to other SDGs, we assessed CAP payments related to farming practices of climate-friendly agriculture (SDG 13) and maintenance of high nature value (HNV) farmland to support biodiversity (SDG 15). We found that the most climate- and biodiversity-friendly farming regions, those with low greenhouse gas (GHG) emissions and a large proportion of HNV farmland, often generate less income than the most climate polluting and least biodiverse regions with high GHG emissions and low fractions of HNV farmland (Figures 2C and 2E). These regions providing public goods also tend to receive the same or less income support per worker,

because decoupled direct payments are area-based. Based on our analysis, average farm incomes across the upper half of regions with the highest agricultural GHG emissions are almost 60% higher than those in the lower half of emitting regions (Figure 2C). Similarly, while HNV farmland is important for biodiversity, the average farm income across the 30% of regions supporting the least HNV farmland is more than twice that of other regions (Figure 2E). The highest GHG-emitting regions are largely in the Netherlands, Belgium, Denmark, United Kingdom, and Ireland with intensive livestock production systems (particularly cattle and pigs), as well as northern Italy where rice is produced (Figure 2D; please see open database of Scown et al.[24] for these and other variables by NUTS2 regions). HNV farmland is relatively abundant in mountain regions of Austria and Italy, Scotland, Croatia, and parts of France and Spain (Figure 2F), where farm incomes are relatively low (Figure 2B). These results suggest CAP payments are biased against, rather than in favor of, marginal regions that provide public goods in the form of climate- and biodiversity-friendly agriculture, which are not rewarded on the market. Thus, the current distribution of CAP payments is not supporting the CAP objective of fair farm income in environmentally friendly farming regions or the interacting social and environmental SDGs related to agriculture throughout the EU.

More than €24.2 billion in income support in our data were paid to regions whose average annual farm income is at or above the EU median disposable income without these payments (orange bars in Figure 3A). Note, however, that the average does not necessarily mean all farmers within these regions earn above the EU median. Nonetheless, income support payments made to regions with incomes below the EU median (blue regions in Figure 3D) indicate a more prudent use of CAP direct payments. We analyzed where the average excess income support was distributed in terms of regional environmental performance, based on GHG emissions and HNV farmland. Almost 70% of the €24.2 billion (€16.9 billion) was paid to the highest 50% of GHG-emitting regions (orange bars in Figure 3B) and almost 58% (€14.0 billion) was paid to the 40% of regions maintaining the lowest fraction of HNV farmland (Greece is excluded from the HNV calculation). The data show CAP income support payments are 1.5 times higher in farming regions producing the most climate pollution than in the lowest-polluting farms, and most of this income support in high-emitting regions also goes to regions with high farm incomes (Figure 3B). Similarly, almost 58% of income support payments made to already market-profitable farming regions (orange bars) also flow to the 40% of regions supporting the least HNV farmland (Figure 3C). These results show that €24.2 billion of CAP income support did not go to regions in obvious need of income support, nor does much of this flow to regions performing well in terms of environmental goals.

We next investigated the aim of the CAP to support rural development, particularly through CAP objective (e) vibrant rural areas, which has the potential to contribute to many SDGs (Figure 1). We assessed where €50.3 billion of CAP funding is geographically allocated by NUTS3 regions (we were able to allocate 85% of the total €59.4 billion payments to a NUTS3 geographic region; see Experimental Procedures), finding only around 38% of this goes to predominantly rural areas (Figure 4). Another 42% goes to intermediate (urban fringe) areas, which may still support rural development (Figure 4). The final 20% (€9.9 billion) goes to predominantly urban areas (e.g., Greater London [all NUTS3 codes within UKI–], which received €64 million in CAP subsidies in 2015). Within the total subsidies for each NUTS3 region, the majority are area-based from Pillar I (dark bars in Figure 4). However, intermediate areas and landowners living in urban areas receive substantial funding from Pillar II for rural development (Figure 4). This rural development funding constitutes 28% (€5.4 billion) of the funding in rural areas, 23% (€4.9 billion) in intermediate areas, and 25% (€2.5 billion) in urban regions (Figure 4). The €2.5 billion in Pillar II payments to urban areas are additional to the €24.2 billion in income support above the EU median. While Pillar II payments to urban areas may represent payment for value-added in a rural area (e.g., if a landowner invested in farmer training programs), it is difficult to demonstrate the intended benefit for rural development from these subsidies.

DISCUSSION

The Same Old CAP Will Not Promote the SDGs

Assessments of the CAP's contribution to the SDGs are few; however, the existing consensus suggests that the CAP's potential can only be realized with significant reallocation of funding among CAP objectives,[15] as well as substantially improving monitoring and evaluation.[23,26] We assessed the potential for the CAP to contribute to achieving its own objectives and, with those, the SDGs by analyzing how well the modern CAP objectives align with SDG targets, and which SDGs are covered by the current CAP monitoring and evaluation indicators (see Experimental Procedures). Our quantitative results, based on the number of CAP objectives and indicators that align with SDG targets and indicators, support the conclusion of other analyses based on expert judgment[15,22] and communication from the European Commission[9] that the CAP has the potential to contribute to most of the SDGs, but our analysis indicates that actually doing so would require substantial reallocation of payments among goals.

The nine modern objectives for the 2021–2027 CAP[14] have the potential to contribute to many SDGs for European societies and the environment; however, a recent analysis by Pe'er et al.[15] shows that the distribution of current funding is highly unbalanced among these nine objectives. Similarly, monitoring and evaluation of the CAP based on the current set of indicators is not optimized to determine whether or not payments are actually contributing to SDGs, because CAP indicators are lacking for many SDGs.[23]

Our findings show that while the CAP indeed has the potential to promote many SDGs in Europe,[9] excessive CAP payments are currently being made to regions that would be relatively well-off anyway (i.e., income support in highly productive farming regions). At the same time, regions where farming systems are providing high levels of public goods through more extensive (less intensive) agriculture are potentially being under-remunerated for provisioning these services. Further, a substantial fraction of CAP payments are supporting already high-income agriculture with high GHG emissions; these payments could be better used (reallocated) to finance environmental

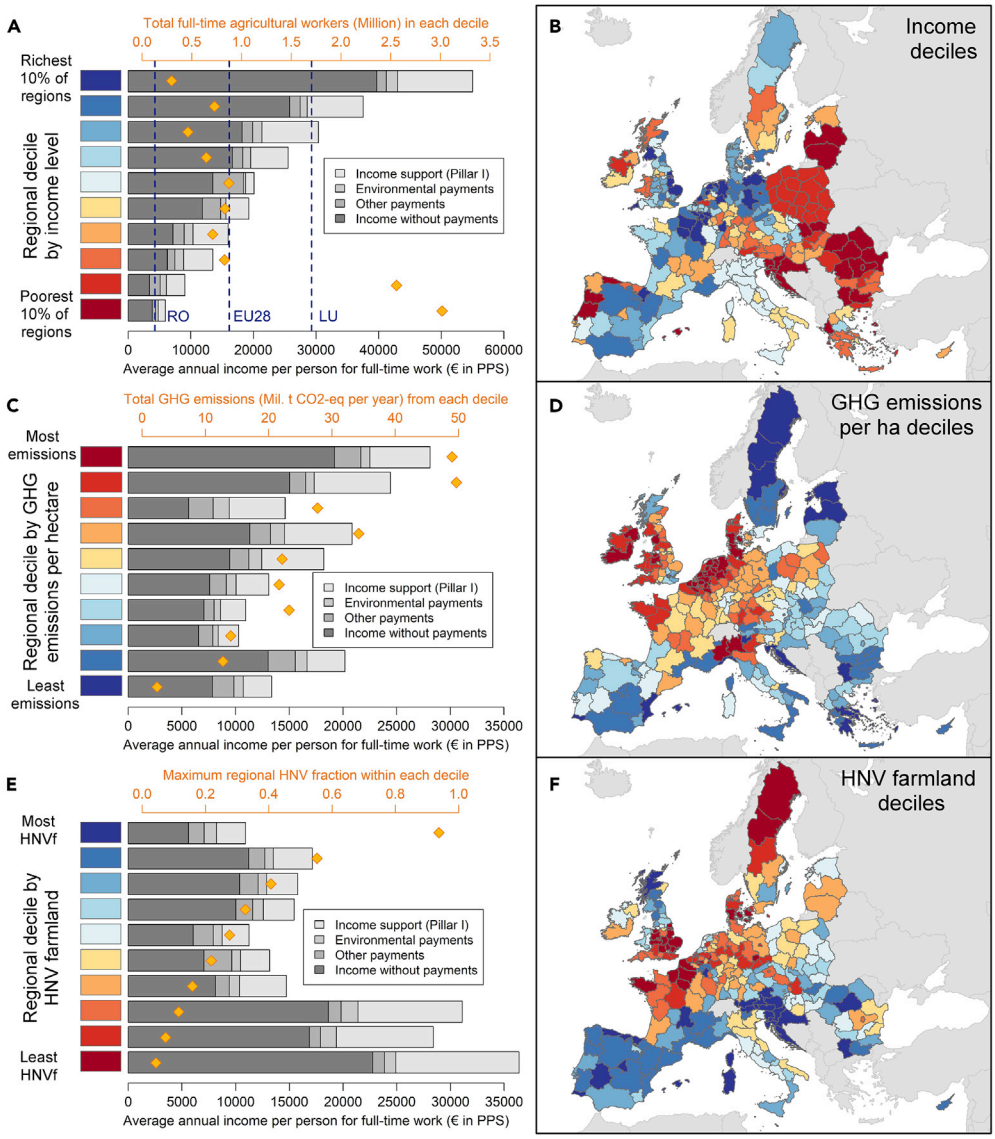

Figure 2. Distribution of CAP Payments against Farm Income and Environmental Outcomes

(A and B) (A) Breakdown of average farm income per full-time worker in NUTS2 regions by decile; consisting of income without payments (market-based farm incomes minus input costs, taxes, and depreciation), plus payments from the CAP, divided into income support via direct payments from Pillar I, environmental payments, and other payments. Bars refer to the lower axis in euros adjusted to purchasing power standard (PPS) within each decile shown in color on the map in (B). Dashed vertical lines show Member State median equivalized net incomes for the lowest-income Member State (Romania), median EU28, and the highest-income Member State (Luxembourg). The total number of full-time agricultural workers (annual work unit [AWU]) in each decile are shown as orange points on the upper axis in millions. Dark blue on the map indicates the top 10% of regions with the highest agricultural income per person, and dark red indicates the 10% of regions with the lowest income.

(C and D) (C) Breakdown of farm income by greenhouse gas (GHG) emissions per hectare of farmland in NUTS2 regions, grouped in deciles and shown on the map in (D). Dark red indicates the top 10% of regions with the highest emission rates, and dark blue indicates the 10% of regions with the lowest emission rates. Total aggregate annual GHG emissions from each decile (in million tonnes of CO_2-equivalents per year, not per hectare) are shown as points on the upper axis.

(E and F) (E) Breakdown of farm income by high nature value (HNV) farmland deciles, shown on the map in (F). Points on the upper axis show the maximum fraction of HNV farmland within any NUTS2 region in that decile. Regions with large fractions of HNV farmland generally have lower average income per person than regions with small fractions of HNV area. Dark blue indicates the top 10% of regions with the largest fraction of HNV farmland, and dark red indicates the 10% of regions with the smallest fraction. Incomes in (C) and (E) calculated as per (A) and bars refer to the lower axis.

Note: CAP payment data were not available for Finland and HNV data were not available for Greece, so these are excluded. Please see Experimental Procedures for full data sources and analyses.

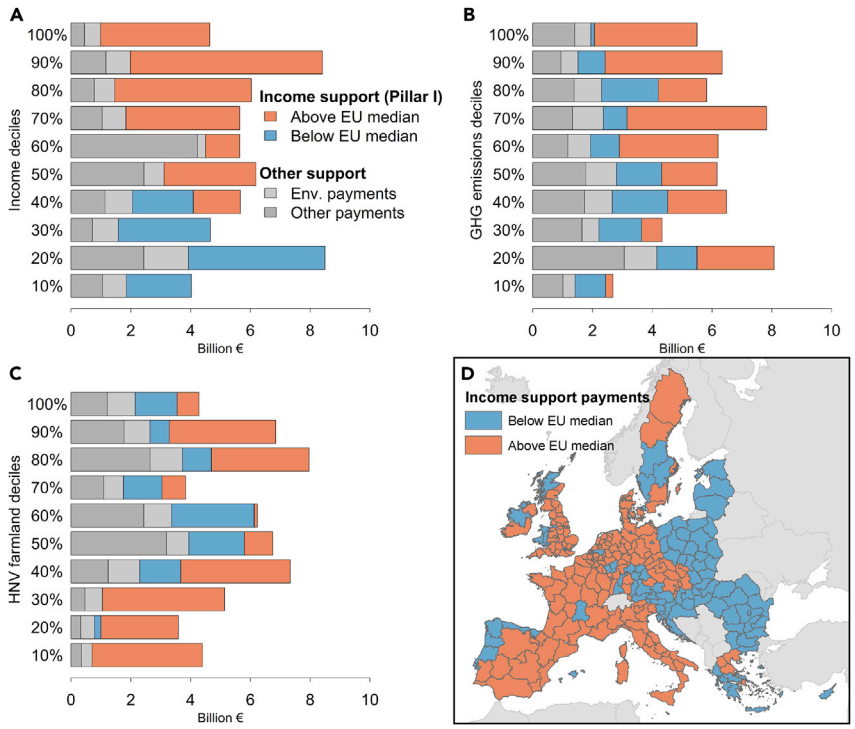

Figure 3. Regional Distribution of Income Support Payments above and below EU Median Income

Payments are shown in relation to regions grouped by farm income and environmental outcomes, separated by regions where average farm incomes were above/below the 2015 EU median disposable income of €16,163 (Figure 2A). Bars represent absolute amounts of payments (in billion €) from all but the darkest gray bars of Figure 2, i.e., all but market income. Deciles groups are shown as percentages (e.g., top 10% of regions based on income labelled "100%").

(A) Breakdown of CAP payments made by farmer income deciles. Orange bars show all income support payments made to regions whose average farm income per person without additional income support is already at or above the EU median disposable income.

(B) Breakdown of CAP payments made by region deciles based on rates of agricultural GHG emissions.

(C) Breakdown of CAP payments by region deciles based on the fraction of high nature value (HNV) farmland.

(D) Map of NUTS2 regions showing where CAP income support payments are made to regions where average farm incomes without income support are above (orange) or below (blue) the EU median. Note: excluded from all panels are NUTS2 regions UKI3, UKI4, CH01, ES63, and ES64, which did not have all the data necessary to perform decile analyses; excluded from (C) are all NUTS2 regions in Greece, which did not have HNV data (please see Experimental Procedures for full details and data sources).

and climate measures (AECMs, or the proposed post-2020 eco-schemes[14]). Similarly, we found a substantial portion of Pillar II funding (the Rural Development Program) actually goes to recipients in predominantly urban areas of the EU, likely having limited if any benefit for rural development. These results suggest that the current distribution of CAP funding is inequitable in terms of needs in different EU regions and in terms of supporting the multiple social and environmental SDGs.

Reallocation of CAP funding from Pillar I to Pillar II and among instruments is therefore needed to increase the likelihood of the policy promoting multiple SDGs while simultaneously fulfilling its own objectives, as opposed to its current focus on a single objective: ensuring farm income. Our analysis supports previous findings that the CAP does not currently achieve additionality for the SDGs or broader societal goals,[15,27–29] and further reveals that at least €24 billion per year could be reallocated to help realize multiple agreed societal goals. This excess income support also more than covers the €20 billion per year that is required to support the commitments of the EU's Biodiversity Strategy,[30] released in May 2020.

Future CAP Unlikely to Realize Substantive Improvements

The details of the post-2020 CAP are currently being wrangled with the Member States. The European Commission claims that the new CAP will bring a fairer distribution of payments among farmers, support action on environmental degradation and climate change, and boost the development of rural areas.[14] The pressing question is whether the new CAP is likely to live up to these claims. We are skeptical due to the lack of measures in the proposal to ensure that a substantial reallocation of payments among objectives occurs. In fact, the instrument ensuring that the majority of payments go to a minority of farmers as income support—the Basic Payment Scheme—will remain as the primary distributive mechanism for the majority of CAP payments.

The Commission claims it is implementing measures to remedy the weaknesses of the income support system. However, it is highly unlikely that these measures will produce a substantial reallocation of payments, because it is, once again, relying on *capping* and *redistribution* to redress the unfair distribution of *decoupled direct payments* that is based on farm size. These measures are identical to those used in the 2013 reform, but with token changes in capping levels. Capping has failed to substantively reduce payments to large farms, as most farms fall under the maximum payment ceiling of €100,000 per farm given the allowance for large farms to deduct their labor costs prior to capping, because average labor costs per hectare are generally higher than payment rates.[31] Further, the potential redistribution to small farms is based on at best a moderate increase in the basic payment *per hectare* to these farms, which is inherently limited in its income potential for small farms. Consequently, large farms will, in all likelihood, continue to receive the lion's share of direct payments and small farms the leftovers, because they have respectively large and small farm areas. Such a result will be a failure of the CAP's attempt to equitably distribute payments among farms and reduce inequalities (SDG 10). We therefore argue that if CAP payments are to serve

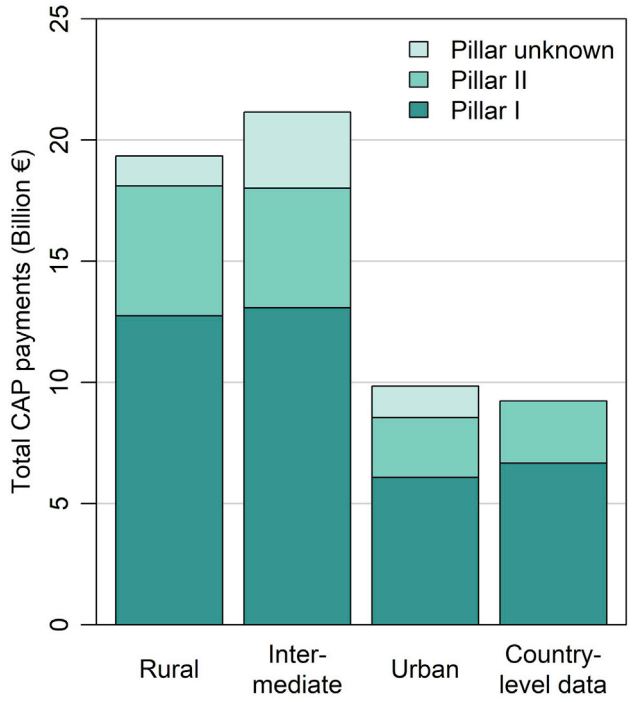

Figure 4. Total CAP Payments to NUTS3 Regions Shown by Urban-Rural Typology

"Predominantly rural" areas (labeled as "Rural") have more than 50% of the population living in rural areas; "intermediate" areas have 20%–50% living in rural areas; and "predominantly urban" (labeled as "Urban") areas have less than 20% living in rural areas.[25] Predominantly urban areas received €9.9 billion of the payments we analyzed, including €2.5 billion designated for rural development under Pillar II. "Pillar unknown" represents schemes reported by Member States not matched to standard CAP terminology (10% of total payments in our data). "Country-level data" means payments could not be allocated to a NUTS3 region due to missing spatial information (n = 9 countries, representing 15% of total payments in our data), thus it is not possible to attribute them to an urban-rural typology. Please see Experimental Procedures for full details. Note: "Pillar unknown" payment for the country-level data was negative in this period, indicating a net repayment from Member States to the EU of €0.2 billion, and so is not shown here.

the purpose of making farming a tenable enterprise (SDG 2), income support payments should only be made to those who have very low incomes by EU standards (recall that presently 82% of direct payments rain down on 20% of farmers).[12] As a result, the €24.2 billion of redundant payments currently made to the high-income group of regions could be more productively redirected to support other goals.

In addition, direct payments have been criticized by economists because they can capitalize into land values (i.e., result in higher land and/or land-rental prices) in which case they will benefit landowners and landlords, and not farmers as intended.[32] However, there is much debate regarding the extent to which capitalization of direct payments actually occurs.[33] National-level studies indicate a range from almost complete capitalization in some regions of Germany,[25] to limited capitalization in Italy.[34] Our results are consistent with these findings in that Figure 2A shows great variation in agricultural incomes across the EU: much of Germany lies within the highest income deciles, while Italy lies around the median. Capitalization occurs when payments increase the profitability of land that is already profitable to farm, such as in the high-income deciles. Capitalization would be expected to occur to a lesser extent, if at all, in low-income deciles where farming has low profitability or it is not otherwise profitable to maintain agricultural land in good condition. Seen together, this indicates that income support is not only redundant in high-income areas of the EU, but it is further likely to line the pockets of landowners who may live anywhere including urban areas, and thus would not even indirectly boost rural economies.

The second measure the Commission is introducing to remedy the weaknesses of the income support system is *conditionality* to improve the environmental performance of the Basic Payment Scheme. However, conditionality is a new term rather than a new measure, because it merges existing measures from the 2013 reform currently contained under two instruments—*cross-compliance* and the requirement for Ecological Focus Areas, and crop diversification associated with *green direct payments* (Table 1)—into a single *conditionality* obligation. Cross-compliance is intended to ensure that if minimum levels of environmental care and other statutory obligations are not respected, then farmers' payments can be reduced. The green direct payment, in turn, has failed to generate significant environmental benefits, due to its flaws as an environmental policy instrument (e.g., high levels of exceptions and lack of potential for spatial targeting).[35,36] In addition, insufficient monitoring and low sanctioning levels have historically hampered conditionality, but the Commission has not addressed these flaws. Consequently, it is unrealistic to expect conditionality to greatly improve the environment, but it may provide some simplification for administrators.

A new environmental initiative is *eco-schemes*, whereby the Commission has made it mandatory for Member States to offer their farmers more flexible Pillar II-type *agri-environment-climate measures* as part of Pillar I. In theory, eco-schemes create the opportunity to reallocate direct payments to dedicated environmental and climate measures, with the flexibility to adapt these to local environmental needs and implement results-orientated payment instruments.[37] Member States, however, have great flexibility to choose how much to spend on these schemes and must make them voluntary for farmers. Tellingly, Member States are permitted to reallocate up to 15% of their Pillar II payments to finance eco-schemes, indicating the potential for the reshuffling of payments for existing agri-environment and climate measures between Pillars, rather than increasing total payments to environmental and climate measuresand thereby generating environmental additionality. Since eco-schemes are voluntary for farmers and there is no obligation to reallocate funding from the Basic Payment Scheme to support them, there is nothing in the proposal to ensure that eco-schemes will generate substantial, additional environmental benefits. Rather, eco-schemes risk taking budgets away from other agri-environment and climate measures that are well established and potentially better instruments. Since Member States face strong political pressure from farmers' organizations to maintain the status quo distribution of payments among farmers and CAP goals,[38] eco-schemes risk continuing the green-washing that characterized the 2013

reform, limiting the realization of the new CAP's potential to contribute to the environmental SDGs.

Rural areas are central to achieving the agriculture- and environment-related SDGs, but what are the chances that the CAP post 2020 will boost development in rural areas? According to the Commission's February 14, 2020, proposal for the EU's 2021–2027 Multiannual Financial Framework, ordinary spending on the Rural Development Program (Pillar II) will be reduced by 24%, while that to Pillar I by only 10% (in constant 2018 prices), which although driven by the UK leaving the EU, is indicative of the political priorities concerning future CAP spending.

Extraordinary funding was proposed on May 27, 2020, to bolster primarily Pillar II by €20 billion for 2021–2027, of which the majority (€15 billion) is sourced from the European Recovery Instrument with the intention "… to address the consequences of the COVID-19 pandemic or the immediate funding needs to avoid a re-emergence of the COVID-19 pandemic."[39] While this funding increases the previous program period funding for Pillar II, the new money is not intended to bolster financing of existing Pillar II measures; the Commission specifies it is emergency aid targeted to support a new, but short-term goal, to "repair the economic and social damage brought by the coronavirus pandemic".

Since the new money does not affect the distribution of the old money between Pillars and measures, it does not affect the conclusions stemming from our analysis: spending imbalances among CAP's modern goals are undermining the CAP's potential to support the SDGs, and hence the goals of the recently communicated European Green Deal[7] and Farm to Fork Strategy.[40] Indeed, the Commission itself acknowledges: "It is clear that we need to do much more to keep ourselves and the planet healthy." Crucially, the potential for CAP post 2020 to "do more" is in the hands of the individual Member States to reallocate CAP funding, because the Commission has created the flexibility to reallocate funding among Pillars and goals/measures if Member States choose to reallocate from the Basic Payment Scheme to eco-schemes.

Although the measures available to Member States in Pillar II will remain largely unchanged, the Commission is hoping that the new *national strategic plans* will leverage development potential. In the future, Member States must detail to the Commission how they will implement both Pillar I and Pillar II in a single plan, as opposed to two separate plans as previously. To what extent this is merely an administrative innovation rather than supporting coherence between the Pillars and thereby promoting sustainable development, remains to be seen. Clearly, it will depend on whether Member States have previously implemented the two pillars independently of each other, which seems unlikely, because it would not have been in their interest to do so. Therefore, given the down prioritizing of Pillar II through the relatively large reduction in funding to its ordinary measures and the absence of new measures (besides the European Recovery Instrument funding that is for extraordinary measures), the Commission is placing a lot of faith in the capacity of the national plans in themselves to boost rural development. Nonetheless, since CAP post 2020 is not likely to generate a significant reallocation of funding from Pillar I to Pillar II, it is also unlikely that it will boost rural development.

Realizing the CAP's Potential for the SDGs

Reforming the future CAP to contribute positively to more SDGs and to optimize trade-offs among potentially conflicting goals requires increased equitability in terms of needs-based spending. Our results, and others,[11,12,15] show inequitable distribution of current payments among recipients, among objectives, and between public and private goods. Scholars have suggested that in high-income countries (sensu the World Bank[41]), such as the majority of the EU, actions to reduce gender and income inequalities (SDGs 5 and 10) have the most synergistic benefits for other SDGs.[42] On the other hand, focusing on only one or a few SDGs can severely constrain or conflict with others.[43] Thus, increasing equitability in CAP payments among recipients in economic need, and among under-supported objectives, is necessary for the CAP to successfully contribute to the SDGs. The current CAP rewards land owners for owning land (a purely private good) and does not provide effective remuneration for providing public goods (e.g., climate mitigation, conservation of biodiversity and landscapes). A better balance could be struck between these objectives by, e.g., moving from general area-based to result-based payments that are spatially targeted.[44]

Also necessary to ensure the CAP will make a valuable contribution to the SDGs in Europe is strategic alignment of objectives, measures, and indicators for monitoring and evaluating the success of the policy.[23,26] Currently, CAP monitoring and evaluation indicators focus on accounting for spending under the policy, rather than assessing the real-world outcomes and impacts relating to its objectives.[15,23] The lack of alignment (Figure 1) between CAP objectives, measures, and indicators weakens monitoring, assessment, follow-up, and review of policies for the SDGs.[26,45] Difficulties in evaluating CAP impacts on sustainability arise from the many different perspectives and priorities in agriculture,[46,47] as well as limited or inaccessible data for monitoring and evaluation;[48] thus, monitoring frameworks require more strategic design. Under the new CAP proposal, Member States would be required to submit their national strategic plans, including a monitoring and evaluation framework.[14] However, caveats in the proposal imply that if monitoring is expensive and burdensome for Member States, it can be largely neglected. A more prudent solution would be to redirect some CAP budget from redundant income support to national CAP monitoring offices, because complex challenges such as the sustainability of agriculture cannot be managed without effective monitoring and evaluation, and adaptation of plans and actions where needed.[49] Payments that are based on evidence of outcomes would also, by design, require that monitoring and evaluation focused on real impacts of CAP payments for social and environmental rather than administrative goals.

Realizing the CAP's untapped potential to support the SDGs requires transparency in how payments are being spent (SDG 16, good governance). Currently, despite EU principles and laws on transparency in reporting these data, basic gaps in data reporting by Member States and a lack of centralized data make it extremely difficult to evaluate what benefits CAP payments provide, but also important, whether benefits are achieved through judicious use of public funds. Moving ahead to the next CAP period, a necessary first step in this direction is that data become more transparent and harmonized.[50] Please see Nicholas et al.[21] for a full description of the spatial database

we used and recommendations for improving the availability of data on CAP payments.

Our analysis focused on three CAP objectives and SDGs: fair farm income, climate action, and protecting biodiversity; but many other SDGs are critical in agriculture[1,51,52] within the broader importance of sustainable food systems.[3,53,54] Good health and well-being of farmers (including mental health[55,56]) are central to agriculture's contribution to the SDGs, but are largely overlooked by the CAP, where the health focus is on consumer demand for healthy food. Similarly, gender equality in agriculture will be key to the sector's contribution to the SDGs,[57] as well as shortening value chains (CAP objective (c)), yet no CAP instruments are dedicated to these issues.[15] These and other SDGs could all benefit from more equitable distribution of CAP spending to ensure all objectives are covered and farmers engaged in sustainable farming are adequately supported.

Overall, we need better ways to achieve food security, landscape stewardship, and rural development with less environmental and climate damage. We have shown that vast financial resources in the CAP are currently misspent in that they do not support achieving these goals. If the EU is committed to being a global leader for the SDGs, as flagged by the Green Deal, then it should start by redirecting these existing resources toward achieving its stated goals.

EXPERIMENTAL PROCEDURES

Resource Availability

Lead Contact

Further information and reasonable requests for resources should be directed to and will be fulfilled by the Lead Contact, Murray Scown.

Materials Availability

This study did not generate new unique materials.

Data and Code Availability

All data and code required to reproduce the results are available on Figshare, https://doi.org/10.23644/uu.12727040. Data may also be found in Nicholas et al[21] on Figshare at https://doi.org/10.23644/uu.12706580.

Aligning CAP Payments, Objectives, Indicators, and SDGs

To evaluate how well the CAP aligns with SDGs in terms of (1) current spending, (2) modern CAP objectives, and (3) monitoring and evaluation indicators, we used a combination of previously published analyses and our own alignment based on keywords in officially stated CAP objectives and SDG targets. The results were visualized in a Sankey diagram (Figure 1), showing: (1) the relative share of current CAP spending aligned with CAP objectives (based on Pe'er et al.[15]); (2) the relative number of SDG targets within each goal aligning with the CAP objectives (our own analysis); and (3) the relative number of CAP indicators aligned with each SDG (from Scown and Nicholas[23]). First, the relative share of current CAP spending aligned with the CAP objectives was taken from Figure S2.3 and Table S2.3 of Pe'er et al.[15] Second, the number of SDG targets aligned with new CAP objectives was determined by analyzing the official wording of CAP objectives[14] and SDG targets.[2] Following the method of Scown and Nicholas,[23] we used keywords, shown in Table S1, to count the number of SDG targets that could potentially be achieved in Europe through action toward stated CAP objectives (i.e., co-benefits for SDGs through CAP objectives). We assumed that if similar themes (reflected in the keywords) appeared in an SDG target and a CAP objective, that target was aligned with that objective. Finally, the relative number of CAP indicators aligned with each SDG was taken from the analysis of Scown and Nicholas,[23] who aligned the CAP monitoring and evaluation indicators (Context, Output, Target, Result, and Impact indicator sets),[58] the Agri-Environmental Indicators used by the European Environment Agency to incorporate environmental concerns into the CAP,[59] and the list of EU SDG indicators used by Eurostat to translate the global SDGs into an EU context.[60]

Analyzing CAP Payments against SDG Needs

To analyze how CAP payments are distributed relative to social and environmental needs relating to the SDGs, we utilized a public dataset of CAP payments centered around 2015, drawn from farmsubsidy.org and made spatially explicit.[21] The distribution of these CAP payments was compared with farm income from Eurostat, agricultural GHG emissions from the Joint Research Centre's EDGAR v4 database,[61] and HNV farmland from the Joint Research Centre and European Environment Agency,[62] using the regions delineated in the Nomenclature of Territorial Units for Statistics (NUTS; 2013 version).[63] No CAP payment data were available for Finland, so it was excluded from all analyses. We also exclude those payments identified as national schemes and those that were paid to recipients outside the EU28 (please see Nicholas et al.[21] for full details of CAP payment data).

First, CAP payment data from Nicholas et al.[21] was aggregated from NUTS3 to NUTS2 level (approximately 260 regions; please see Eurostat[63] for details) in order to align with the resolution of Eurostat data. CAP payments in the original database for ten countries (BG, CZ, EE, EL, IE, LT, LU, LV, RO, SI) were not disaggregated below the country level (NUTS0), so these were manually allocated to a NUTS2 region based on the share of national utilized agricultural area (UAA) within each NUTS2. The use of UAA to manually allocate CAP payments from NUTS0 to NUTS2 was justified because the vast majority of CAP payments are area-based. For EE, LT, LU, and LV, NUTS0 and NUTS2 in the 2013 version are equivalent. For the remaining six countries (BG, CZ, EL, IE, RO, SI), the method of manual allocation of CAP payments to NUTS2 was validated by performing the same allocation from NUTS0 to NUTS2 for all countries that did have disaggregated data, then comparing the results between original and manually allocated NUTS2 data. This validation showed that manual allocation based on UAA had a mean absolute error of €43 million (less than 0.1% of the total payments), which was inflated by only eight outliers that had an absolute error over €200 million (Figure S1). Overall, more than 79% of NUTS2 regions had a manually allocated value within 30% of the true value. Furthermore, the final NUTS0 to NUTS2 manual allocation using UAA was only applied to six countries, representing less than 12% of the total payments. The 18 countries with CAP payments at the NUTS3 level also had small proportions of payments not disaggregated below the NUTS0 level (€1.2 billion or 2% of total payments), and these were excluded from the analyses to not introduce further uncertainty where NUTS3 data were available.

Next, we grouped NUTS2 regions into deciles (approximately 26 regions per decile, reflecting the approximately 260 NUTS2 regions) based on farm income, GHG emission rates, and HNV farmland, then analyzed payments by these deciles. For farm income, we used a measure of income per person per year engaged in full-time farm labor (agricultural factor income [AFI] per annual work unit [AWU]), adjusted to PPS to reflect equal ability to buy goods and services in different countries. We took the average AFI and AWU from 2010 to 2017 to fill annual gaps in Eurostat data and to account for inter-annual variability. We then grouped regions into deciles by per hectare rates of GHG emissions from agriculture and fraction of HNV farmland, and again analyzed CAP payments by these groups (please see Supplemental Experimental Procedures for full details of how these indicators were processed).

The results of decile analyses are visualized as bar charts and maps in Figures 2 and 3. NUTS2 regions grouped into deciles are mapped for Europe (excluding outlying EU territories). For farm income and HNV farmland, red regions in Figure 2 indicate NUTS2 regions in the lowest deciles (i.e., low income or low fraction of HNV farmland) and blue regions are those in the highest deciles (i.e., high income or high fraction of HNV farmland). For GHG emissions, the highest per hectare emitting regions are mapped red and the lowest are blue. Bar charts alongside maps in Figure 2 show the average annual income per full-time farm worker (€ in PPS) within each of the deciles, disaggregated by income without subsidies, income support payments (Pillar I), environmental payments, and other payments (please see Table S2 for full details of which payment instruments were included in each category). To qualify as an environmental payment, we applied the following definition to the description of every measure available under both Pillars, thereby capturing measures other than those designated agri-environmental schemes or agri-environment-

climate measures under Pillar II that also have a main objective of benefiting the environment.

Definition: We define an environmental payment to include all CAP measures that state the intention to principally benefit nature, the environment, climate, or promote sustainable farming in the wording of the measure itself, and that involve more than the application of usual good farming practice or directly support production. This definition does not identify the impact of the measures in practice but attempts to distinguish those measures that explicitly aim to benefit the environment. We checked the correspondence between measures from different payment periods (2007–2013 and 2014–2020) assessed the measure wording independently for each period.

NUTS2 regions summarized in each of the bars of each chart are the NUTS2 regions in those particular deciles (i.e., income deciles, GHG emission deciles, and HNV farmland deciles). Also shown on the bar charts in Figure 2 are the total number of full-time agricultural workers in each income decile, the total GHG emissions from each GHG decile, and the maximum fraction of HNV farmland in each HNV farmland decile. In addition to the exclusion of Finland, four NUTS2 regions were excluded from each of these analyses (UKI3, UKI4, ES64, and ES65) because of zeros or no data in either AWU (labor force), UAA (agricultural area), or GHG emissions. All of Greece was excluded from the HNV farmland analysis because of no available HNV data.

Next, we identified and isolated all income support payments that were made in NUTS2 regions with an average farm income at or above the 2015 EU median equivalized net income of €16,163 (adjusted for PPS). This total amount of income support distributed to regions above the EU median income is visualized as orange bars in Figure 3.

Finally, we analyzed the distribution of CAP payments under Pillar I and Pillar II (designated for rural development) against the Eurostat urban-rural typologies.[64] We used NUTS3 as the spatial unit here, as opposed to NUTS2, because the Eurostat urban-rural typologies are applied at the NUTS3 level (please see Eurostat for details on NUTS regions[63] and urban-rural typologies[64]). CAP payments that could not be allocated to a NUTS3 unit (due to missing spatial information in the original data) or to a particular CAP Pillar were kept separate from this analysis.

SUPPLEMENTAL INFORMATION

Supplemental Information can be found online at https://doi.org/10.1016/j.oneear.2020.07.011.

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AUTHOR CONTRIBUTIONS

Conceptualization, M.W.S., M.V.B., and K.A.N.; Methodology, M.W.S., K.A.N., and M.V.B.; Formal Analysis, M.W.S.; Investigation, M.W.S., M.V.B., and K.A.N.; Writing and Revisions, M.W.S., M.V.B., and K.A.N.; Visualization, M.W.S.; Funding Acquisition, K.A.N.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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