Dryland Cropping May Present a Cost-Effective Response to Dust From Idled Lands

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Agricultural lands idled to reduce groundwater demand in California's Central Valley can generate dust and pose risks for rural communities. To avoid the worst impacts, it may be necessary to support productive alternatives like dryland farming or other mitigation measures.

Overdraft of groundwater has led to land subsidence, infrastructure damage, water quality impairments, and the depletion of drought reserves in many of California's groundwater basins. The Sustainable Groundwater Management Act (SGMA), legislation passed in 2014, calls on local governing bodies to develop and implement plans to bring their groundwater basins into balance by the early 2040s.

However, the path to sustainability is fraught with difficult choices. In the San Joaquin Valley, home to most of the state's critically overdrafted basins, making up a two million-acre-foot annual groundwater deficit will require managing demand, most of which comes from agriculture. The valley could see half a million acres of cropland come out of irrigated production by the early 2040s, and potentially more, without new sources of supply (e.g., groundwater recharge).

The question of what happens to this newly fallowed cropland—or how to avoid fallowing altogether—is important both for the region's economy and for the well-being of valley communities. Fallowed cropland, whether left idle or tilled to manage weeds, can be a significant source of dust emissions. Wind mobilizes small soil particles from bare ground and lifts them into the air, dispersing them and exposing nearby communities. Coarse particulate matter (particulates 10 microns or less in diameter, PM_{10}) has been shown to negatively impact human health, particularly in children, and increased dust emissions from idled cropland could hinder the valley's recent progress on air quality.

Protecting communities from these impacts depends predominantly on disrupting the wind erosion processes that generate dust in the first place. Covering the ground with wind-stable elements such as mulch has been successful elsewhere, but it is expensive. Establishing vegetative cover is likely the simplest and most cost-effective solution for slowing wind speeds on the ground and inhibiting dust generation.

Adopting alternative, productive land uses presents an opportunity to achieve this mitigation while also minimizing the economic downside of fallowing. In particular, planting a winter dryland crop, such as a cereal or forage, could be one way to reduce dust and generate revenue. Dryland crops are produced only with rainfall and stored soil water. Some areas of the valley could likely establish these crops with no irrigation; elsewhere, small, targeted irrigation events—termed "water-limited" cropping here—could greatly reduce agronomic risks.

While both dryland and water-limited cropping can be challenging in drier areas of the valley, in some cases they could be viable alternatives to fallowing that mitigate dust and offset the costs of fallow management. Economic support to promote public benefits—whether for dryland cropping systems or other mitigation actions—could help reduce risks in priority areas.

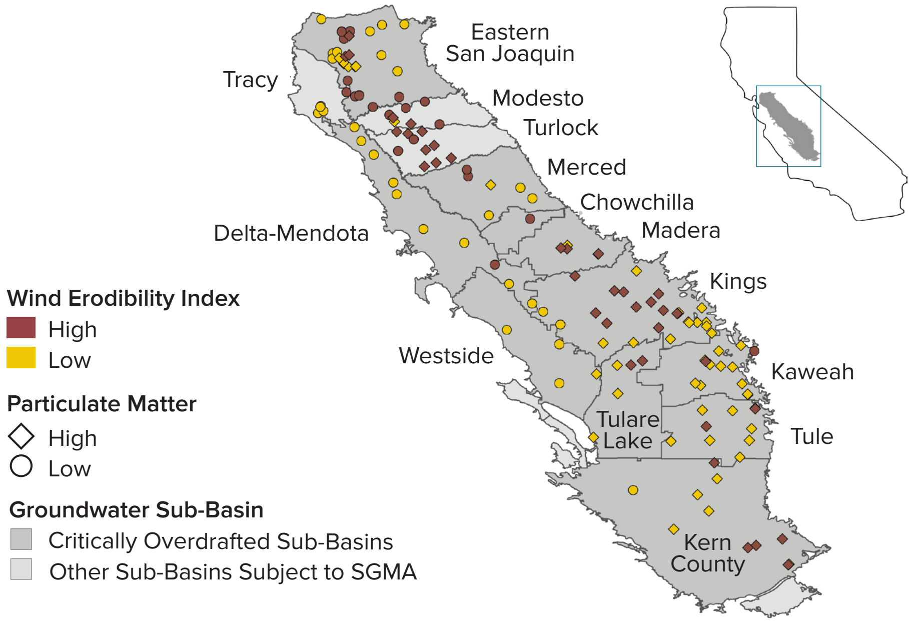
Understanding Dust Risk in the San Joaquin Valley

To understand the potential dust risks posed by large-scale land fallowing, we first characterized the net effect of idling lands on local concentrations of particulate matter. Regional stakeholders are particularly interested in this question because some tilling and harvest activities already generate significant emissions from agricultural lands. Second, we mapped the distribution of dust risk in the valley according to soil erodibility and baseline particulate matter concentrations. We focused on small rural communities, where nearby fallowing could cause immediate problems.

To analyze how different land cover types relate to local particulates, we compiled an annual dataset of groundwater basins from 2010–2016. It combines acreages of six major land cover types from the USDA Cropland Data Layer with local particulate matter (fine particles below 2.5 microns in diameter, $PM_{2.5}$) concentrations from NASA. We also controlled for wildfire activity during our analysis period with burn data from CAL FIRE.

This analysis supports two conclusions. First, the net effect of idling irrigated agricultural lands on local particulates depends on crop type: while idling annual crops (such as vegetables) would likely increase particulates, current harvest techniques for some orchard crops generate enough dust that idling may reduce particulate concentrations. Second, timing matters. Dust generation from orchards occurs primarily in late summer and early fall during harvest. Overall, relationships between land cover and local particulates are weakest in winter, when large wind events are less frequent.

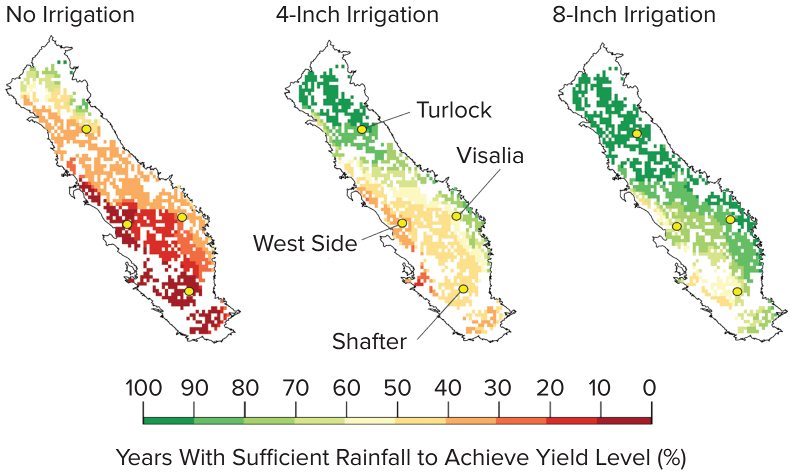
Figure 1. Distribution of Dust Risk Across San Joaquin Valley Communities



Source: Authors' estimates using data from NASA SEDAC (particulate matter concentration) and UC Davis (Wind Erodibility Index). Details in Ayres et al. (2022).

Note: Plotted points are community water systems and outlined areas are groundwater sub-basins. Dust risk is based on the Wind Erodibility Index (high: WEI>86) and particulate matter (PM) averages (high: ambient $PM_{2.5}>12$ μg/m^3 over 2010–2016). All values are calculated within 1.5-mile buffers.

Figure 2. Probability of Attaining 5-Ton Winter Wheat Forage Yields Across the San Joaquin Valley



Source: Authors' estimates; precipitation from PRISM Climate Group; cropland mapping from the California Department of Water Resources. Details in Peterson et al. (2022).

Note: Probabilities reflect the relationship between simulated winter wheat biomass production and total water input (rainfall + irrigation), spatially extrapolated using PRISM 10-year average rainfall.

Dust risk varies across the valley. While particles can sometimes travel long distances from their source, landscape-based dust tends to contain larger particles that generate localized impacts. Rural areas surrounded by farmland are at the greatest risk, and we investigated their surrounding soil characteristics to characterize risk differences among them.

Using a dataset of water systems from the State Water Resources Control Board, we identified 147 rural locations surrounded predominantly by farmland. We summarized 1) soil erodibility using the USDA NRCS Wind Erodibility Index (WEI) and 2) local particulate concentrations using the NASA data described previously, and then defined thresholds for these variables to denote high risk.

Of the valley's rural communities, 63 face high risks due to erodible soil types (Figure 1). These are spatially concentrated in the valley's central-east and north-central areas, and most also exhibit high baseline particulate concentrations—a common feature of valley communities. The ultimate distribution of risk across communities will chiefly depend on where land is idled, including how farmers trade water to avoid fallowing. If there is no trading, and water-use reductions occur in areas with the greatest overdraft, the majority (75%) of high-risk locations will see fallowing, but this outcome could change significantly with trading of surface water and groundwater.

Dryland Crops Could be a Viable Dust Solution in Some Areas

Dryland crops offer a productive alternative to fallowing and can mitigate dust risks, but growing conditions across the valley vary substantially. Using the crop model APSIM (www.apsim.info), calibrated with empirical data from winter cereal field trials, we simulated winter wheat forage production for 20 years of historical weather at key sites in the San Joaquin Valley. Because rainfall constrains dryland crop productivity, we mapped the likelihood of successful crop establishment and productivity across the valley based on the relationship between modeled yield and average rainfall.

Grain yields can be low in dryland systems, so the most efficient use of water is often to harvest winter cereals for forage. In areas that receive less than 10 inches of rainfall annually, such as the southern and western portions of the valley, dryland wheat forage would fail in most years (Figure 2). In contrast, water-limited wheat that receives one to two applications of 4 inches of irrigation could produce five tons per acre of forage on orders of magnitude more land across the valley. If the crop and its residues are managed carefully, these systems could also control dust emissions.

But does this tactic pencil out? Not all areas that are suitable according to these models will actually transition from irrigated to dryland or water-limited crop production. Other considerations beyond agronomic potential will affect where and when these systems make sense as an alternative to land fallowing. For example, water-limited crops gain tractability when other lucrative land use options are unsuitable, small quantities of water cannot be banked or transferred elsewhere, or growers wish to implement a flexible crop that can be sacrificed should recharge floodwaters become available. Furthermore, water-limited crops are more likely to be financially self-supporting where growers can keep operating costs low.

We consulted UC Davis cost and return studies for winter wheat grain and forage and adjusted the assumptions to better reflect water-limited crop systems as well as recent price trends. Prices for forage products vary dramatically from year to year, so financial outcomes are sensitive to cost and price scenarios. When hay prices are high, positive net returns may be possible across a wide range of forage yields (Table 1). But at lower prices, higher yields are required to keep operations profitable. Such yields may not be possible in low-rainfall areas of the valley, or when supplemental irrigation is infeasible.

Table 1. Net Operating Returns for Dryland (No Irrigation) and Water-Limited (8-Inch Irrigation) Forage Marketed as Hay

a) Net Operating Returns for High-Cost Assumptions

	No Irrigation					**8-Inch Irrigation**				
	Hay Price ($/Ton)					Hay Price ($/Ton)				
Hay Yield (Ton/Acre)	100	120	160	200	240	100	120	160	200	240
1	-157	-137	-97	-57	-17	-618	-598	-558	-518	-478
2	-107	-67	13	93	173	-568	-528	-448	-368	-288
2.5	-82	-32	68	168	268	-543	-493	-393	-293	-193
3	-57	3	123	243	363	-518	-458	-338	-218	-98
4	-7	73	233	393	553	-468	-388	-228	-68	92
5	43	143	343	543	743	-418	-318	-118	82	282
6	93	213	453	693	933	-368	-248	-8	232	472

b) Net Operating Returns for Low-Cost Assumptions

	No Irrigation					**8-Inch Irrigation**				
	Hay Price ($/Ton)					Hay Price ($/Ton)				
Hay Yield (Ton/Acre)	100	120	160	200	240	100	120	160	200	240
1	-137	-117	-77	-37	3	-299	-279	-239	-199	-159
2	-87	-47	33	113	193	-249	-209	-129	-49	31
2.5	-62	-12	88	188	288	-224	-174	-74	26	126
3	-37	23	143	263	383	-199	-139	-19	101	221
4	13	93	253	413	573	-149	-69	91	251	411
5	63	163	363	563	763	-99	1	201	401	601
6	113	233	473	713	953	-49	71	311	551	791

Source: Authors' estimates based on expert input and UC Davis cost and return studies for winter wheat grain and forage. Details in Peterson et al. (2022).

Note: The 8-inch irrigation scenario represents two 4-inch applications. Net operating returns are for a) high-cost assumptions ($500/acre-foot water, $0.75/pound nitrogen fertilizer, $5/gallon diesel) and b) low-cost assumptions ($100/acre-foot water, $0.42/pound nitrogen fertilizer, $4.16/gallon diesel). Costs for labor and inputs, such as seed and herbicide, are identical for both scenarios. Costs do not include overhead.

We found that, for a range of cost assumptions, four-ton forage yields resulted in positive net operating returns unless hay prices fell to $120 per ton. Five-ton forage yields resulted in more comfortable margins. However, when operating costs were high—we assumed $500 per acre-foot for water, $0.75 per pound for nitrogen fertilizer, and $5 per gallon for diesel fuel, in addition to costs for other inputs and labor—hay prices below $120 per ton still resulted in negative net operating returns at the five-ton yield level. Note that our estimates of operating costs did not include overhead (e.g., land rental); this is an important caveat, as operating returns would need to be high enough to cover overhead to result in a net profit.

Strategic applications of small amounts of irrigation on winter forages could represent a competitive value for water. Under a scenario with moderate costs and prices—$165 per ton hay price and $300 per acre-foot of water—going from zero to two applications of supplemental irrigation increased net returns by roughly $200–$300 per acre. This translates to $320–$460 per acre-foot of water, comparable to the marginal value of irrigation water for some of the valley's more profitable crops.

Other Ground Cover Approaches for Dust Mitigation Have Varying Costs

When there are agronomic or economic barriers to water-limited crop production, cover cropping, strip cropping, and other low-intensity approaches to maintain vegetative cover offer an alternative mitigation option. Likewise, interventions that cover or alter the landscape to reduce wind erosion have proven effective elsewhere in California. We combined a review of cost estimates from federal programs, additional cost studies, and interviews with valley land managers to estimate costs for these approaches.

Landscape alterations, often using gravel or mulch to cover the ground, can minimize dust for long periods of time if undisturbed, but they are also costly. Per-acre costs of several hundred or even thousands of dollars (2019 USD) will render them unattractive, especially if lands taken out of irrigated production are not contiguous and cannot benefit from economies of scale. However, there are some emerging, lower-cost options: mulch from decommissioned orchards and nut processing byproducts such as almond hulls can also be spread to reduce dust.

In contrast, vegetative cover and wind barriers can be established and reduce dust generation for much less. These measures need not cover the entirety of an idled field, which provides potential cost reductions. Cross-wind vegetative strips, for example, could cover as little as 20% of the field and cost as little as $10–30 per acre (2019 USD). However, the average per-acre cost depends on the size of the project, the method used to distribute seeds, the need for additional inputs (such as fertilizer), and maintenance requirements. These approaches are flexible, and some have a history of success elsewhere in California and the West.

As noted above, establishing vegetation in arid landscapes is challenging. Beyond water needs, new plantings also must contend with the legacy of fertilizer and other agricultural inputs that create conditions favorable for weed competition—which can reduce the likelihood of success and increase maintenance costs. Efforts to establish native vegetation for dust control on formerly irrigated lands in the nearby Antelope Valley encountered difficulties with weed competition, and reports emphasized the role that chance rainstorms played in supporting establishment of planted natives by providing much-needed moisture. Moving forward, these difficulties may grow as climate change increases drought intensity and air temperature, placing greater stresses on unirrigated plants.

Effective Mitigation May Require Support

As groundwater managers work with pumpers to reduce groundwater use, they will need to consider the consequences of reduced irrigation water availability. Where dryland farming can be profitable, it can help offset local economic losses from reduced water availability while alleviating dust impacts. Where land losing access to irrigation water doesn't have a clear productive use and must be actively managed for dust, it may become a financial liability—and complicate efforts to close groundwater deficits. In these cases, financial support for dust mitigation can expand opportunities for reducing risk in priority areas and alleviate the impacts of water scarcity on land value.

Existing programs can enable land transitions that responsibly control dust. For example, the NRCS Environmental Quality Incentives Program already supports similar activities elsewhere, and the state's new Multi-Benefit Land Repurposing Program can facilitate integrated solutions. Proactively setting up accessible systems can ensure solutions are ready to go when needed, helping to avoid costly environmental impacts on the valley's rural communities.

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For additional information, the authors recommend:

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