
Collaboration, Participation and Technology

The San Joaquin Valley Cumulative Health Impacts Project

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Community-university partnerships have been shown to produce significant value for both sets of partners, providing reciprocal learning opportunities, (re)building of bonds of trust, and creating unique venues to formulate and apply research that responds to community interests and informs collaborative solutions to community problems (Peterson, Minkler & Vásquez 2006; Minkler & Hancock 2003, Seifer 2003; Tajik & Minkler 2006). For such partnerships to be mutually empowering, certain design characteristics are necessary, including respect for different modes and expressions of knowledge, capacity-building for all parties, and an environment that promotes honest and constructive dialogue about inevitable tensions associated with the interplay of knowledge and power. This article explores an innovative case of community-university partnerships through participatory action research involving a coalition of environmental justice and health advocates, the San Joaquin Valley Cumulative Health Impacts Project (SVJ CHIP), and researchers affiliated with the University of California, Davis.

University and community partners in SVJ CHIP developed a strategy to document cumulative health impacts of multiple types and sources of pollution; to inform policy change to improve environmental and health policies; and to empower community members to use research to advocate on their own behalf. Produced through a collaborative writing process with university and community partners, this article critically addresses the complex and challenging interactions between scientists and social movements and the use of participatory action research (Fals-Borda 1992; Hall 1992; Israel et al. 1998; Nyden & Wiewel 1992; Stoeker 2003) and a Public Participation Geographic Information System (PPGIS) (Elwood 2002; Elwood & Leitner 1998) to intervene in regional power structures and address cumulative health impacts.

METHODS AND KEY FINDINGS

This article seeks to answer three research questions: (1) How can a PPGIS process be employed to build effective and sustainable

community-university partnerships? (2) Conversely, how does a PPGIS process depend on such partnerships? (3) Prompted by these questions, how does engagement in a PPGIS process transform not only the knowledge base but the *ways of knowing* of its partners?

The project was based on a participatory action research approach that developed a double-loop learning process (Argyris 1976) in which academic and community partners could share and continually and critically reflect upon their own knowledge of and ways of knowing the social and environmental dimensions of the San Joaquin Valley region. Project partners engaged in a praxis in which the documentation of environmental justice issues through PPGIS mapping were subjected to a continuous dialogue, critique and refinement process, drawing on the diverse expertise of all members. The research methods for this article are participant observation and reflexive analysis by the study authors of the planning meetings and workshops during the two-year (and counting) project period. These observations were documented in field notes and reflective dialogue between the study authors. In addition, the authors analysed written and visual records of maps, meeting minutes, project reports and other project documents.

The community-university and participatory action research approach in this project offers two major findings:

- Public Participation GIS does not merely document community knowledge, but can promote mutually beneficial co-learning between academics and advocates, as well as spatial representations and analyses that reflect the multiple scales of social movement organising.
- The sustainability of community-university partnerships is not based on a lack of mistakes in the relationship, but instead on the ability to build resilience over time and draw strength from responses to challenges experienced and overcome.

COMMUNITY-BASED PARTICIPATORY RESEARCH, BOUNDARY OBJECTS AND PPGIS

Drawing on the foundational texts and praxis of Fals-Borda (1992), Freire (1982), Hall (1992) and others, Minkler (2004, p. 684) defines community-based participatory research (CBPR) as underscored by 'ethical principles such as self-determination, liberty, and equity and reflects an inherent belief in the ability of people to accurately assess their strengths and needs and their right to act upon them'.

Despite the potency of CBPR to address social inequities, including the hierarchies of power/knowledge between researchers and communities, practitioners also acknowledge a range of tensions with the approach. DeLugan and colleagues (2010, p. 8) observe that 'a tension may exist between academic standards for indicator selection and measurement, and a community's interests likely guided less by academic standards'. This tension is also identified by Nyden and Wiewel (1992) as something to 'harness', while Stoeker (2003) answers his question about CBPR 'are academics irrelevant?' with a qualified 'no' – as long as there

is continuous, critical and reciprocal reflection on the play of power in the relationship and on the interdependent roles of both academics and communities.

One innovative approach to CBPR that addresses some of these tensions is the Public Participation Geographic Information System (Elwood 2002). In PPGIS, researchers and community advocates collaborate to develop digital maps that represent high-priority issues and incorporate community knowledge. This process is intended to help participants develop a sense of ownership over the map products created for their use and to elicit new information or feedback on how maps can be changed to better suit community and advocacy needs. This public participatory use of GIS is both educational and political in that it seeks to expand access to technology and spatial data to groups that may not traditionally have had access to such resources, including low-income communities and communities of colour.

The maps produced through the PPGIS process can be understood as ‘boundary objects’ (Gieryn 1983; Star & Griesemer 1989) that serve to bridge—albeit unevenly—cultures of knowledge and resources for ‘boundary movement repertoires’ (Brown 2007; Brulle & Pellow 2006) whereby distinctions between science and non-science, experts and laypeople are blurred ‘in order to negotiate the meaning of science and to challenge the definitions of acceptable scientific practices and products’ (McCormick, Brown & Zavestoski 2003, p. 547). A critical avenue for such democratisation has been through ‘citizen-science alliances’ (Brown 2007) and ‘street science’, which refers to ‘a practice of science, political inquiry, and action [that] originates and evolves in a community’ (Corburn 2005, p. 44).

Liévanos and colleagues (in press) describe the relationship between ‘street science’ and university/academic research science in the San Joaquin Valley in ways that highlight both the areas of connection and the discontinuities that must be negotiated in any university-community partnership. One arena for the convergence of street and academic research science is around the emerging concepts and methodologies of cumulative environmental and health impacts. Attention to cumulative impacts is based on understanding that human health is a product of multiple factors operating in conjunction and over time (Lynch, Kaplan & Shema 1997; Schafer et al. 2004). By tracing the lived reality of those at risk of exposure, a cumulative impact approach can begin to systematically address the factors that expose certain populations to specific combinations and concentrations of chemicals (Krieg & Faber 2004). The collaboration between university researchers and community advocates developed through the SJV CHIP process represents an innovative and productive negotiation of these different cultures of knowledge, focused on documenting cumulative health impacts through the methods of GIS and community-produced mapping.

REGIONAL CONTEXT

California's San Joaquin Valley, a region comprised of eight counties in the southern expanse of the Central Valley, extends for 470 km and is home to 5.4 million residents (see Figure 1). The San Joaquin Valley is world renowned for its industrial agricultural production but also suffers from the social, environmental and political implications of this economic engine, including industrial applications of pesticides and the exploitation of an inexpensive – often sociopolitically isolated – immigrant farm labour population (Cole & Foster 2001; Harrison 2006, 2008; Liévanos, London & Sze in press; London, Sze & Liévanos 2008; Pulido 1996; Sherman et al. 1997; Villarejo et al. 2000; Walker 2006).

Figure 1: California's San Joaquin Valley (Huang and London 2010)



Sometimes called the 'other California' (Haslam 1994) and compared to Appalachia with its concentrated poverty and associated social ills (Congressional Research Service 2005), the San Joaquin Valley is a land of 'poverty amidst prosperity' (Martin & Taylor 1998). Populations of largely low-income immigrants from around the world (but with a predominant representation from Mexico, including significant numbers of indigenous and undocumented persons) live and work in communities heavily affected by the toxic externalities of agricultural and industrial production in the region (Pulido 1996).

Air and water pollution are two consequences of industrial agricultural production in the region which have significant

negative impacts on residents' health (for background on water pollution see Firestone 2009). As a result of air pollution generated by stationary agricultural and industrial sources, coupled with the automobiles and diesel trucks that stream through the region's highways, residents of the San Joaquin Valley suffer from high rates of asthma and other respiratory ailments (Ngo et al. 2010).

Vulnerability factors for residents, such as those living near freeways, working in outdoor occupations with inadequate safety precautions, drinking polluted water, and lacking health insurance and access to quality medical care, create what Morello-Frosch and colleagues (2001) call a 'riskscape' that disproportionately disadvantages those with the least means to protect themselves and their families. Many of these residents live in unincorporated communities and therefore lack direct local representation to address these issues and to hold policy-makers accountable (Anderson 2008; Rubin et al. 2007).

Drawing inspiration and organising tactics from the United Farm Workers, civil rights and related struggles, the environmental justice movements in the San Joaquin Valley have encompassed campaigns on issues ranging from pesticides exposures, diesel exhaust impacts, access to clear drinking water and toxic waste dumps, to air and water contamination from industrial dairies and other agricultural production, and more recently climate justice (Harrison 2006; Liévanos, London & Sze in press; Pulido 1996). Activists have mobilised across scales – linking community struggles with regional, state-wide, national, and even global justice movements (Cole & Foster 2001; Harrison 2006, 2008; London, Sze & Liévanos 2008). The activists that would form SJV CHIP were leaders in this movement to give voice and power to the populations struggling most directly with these environmental inequities.

THE SAN JOAQUIN VALLEY CUMULATIVE HEALTH IMPACTS PROJECT

The San Joaquin Valley Cumulative Health Impacts Project (SJV CHIP) was founded in April 2009 by a coalition of environmental health and social justice organisations representing low-income communities and people of colour in the San Joaquin Valley in their environmental justice struggles. Advocates recognised that environmental permitting, regulatory processes and local policy-making could provide greater environmental protection for and improve the health of families, communities and the economy if pollution sources were reviewed and considered in a comprehensive way. While the concept of enhancing public policy through the documentation of cumulative health impacts had been discussed among San Joaquin Valley justice advocates for years, there had been little action towards this end due to the limited capacity of the advocates to effectively engage with the relevant science and scientists.

Environmental justice and health activists in the San Joaquin Valley were inspired by *Still Toxic After All These Years*

(Pastor, Morello-Frosch & Sadd 2007), based on a community-university partnership with the Bay Area Environmental Health Collaborative (BAEHC) cumulative health impacts campaign. This report, and the campaign it informed, resulted in a commitment by the San Francisco Bay Area Air Quality District to reduce cumulative environmental impacts, although regional activists continue to press for the district to formally adopt a cumulative health impacts assessment method. This precedent prompted discussions among advocates in the San Joaquin Valley about the desirability and feasibility of launching a similar cumulative impacts campaign among members of existing coalitions in the region. These discussions reached a decisive point at a health-foundation-sponsored conference where academic and community partners associated with the BAEHC presented their work, and activists from the San Joaquin Valley experiencing what they called ‘research envy’ articulated their interest in developing a similar process in their region that could provide credible science to inform policies that promoted environmental, economic and social health.

The organisations that founded SJV CHIP included the Central California Environmental Justice Network; Central Valley Air Quality Coalition; Californians for Pesticide Reform; California Prison Moratorium Project; California Rural Legal Assistance Inc./ Foundation; Catholic Charities Diocese of Stockton; Center on Race, Poverty and the Environment; Fresno Metro Ministry; Greenaction for Health and Environmental Justice; Medical Advocates for Healthy Air; and the SJV Latino Environmental Advancement Project. What is remarkable about SJV CHIP is both its breadth – encompassing most of the most active and effective environmental justice organisations in the region, with a particular focus on air quality and pesticides – and how these leaders were willing and able to dedicate time beyond their already overcommitted schedules to a new collaborative effort. At the same time, members understood that the individual and organisational strains of this overload were unsustainable and a central challenge to their long-term success.

During an initial set of exploratory planning meetings, SJV CHIP community leaders defined the qualities of engagement they sought with potential academic partners. Based on existing relationships with researchers at the University of California at Davis (UC Davis) Center for Regional Change (<http://regionalchange.ucdavis.edu>) and the UC Davis Environmental Justice Project (<http://ej.ucdavis.edu>), the SJV CHIP invited UC Davis researchers to develop a collaborative project together.

At the same time, UC Davis researchers had received funding from the Ford Foundation to develop participatory action research projects in California and were interested in focusing some of this support within the San Joaquin Valley. The UC Davis Environmental Justice Project (EJP) and the Center for Regional Change (CRC) focus on solutions-oriented and community-engaged research, as well as the integration of social equity into research

and policies on sustainability. Developing sustained partnerships with key regional actors such as SJV CHIP is a crucial part of carrying out this applied research mission. More broadly, as a public land grant university, UC Davis is committed to conducting research that serves the interest of the people of California and can be applied to solving pressing social, environmental and economic problems facing the state.

Initial meetings between SJV CHIP members and UC Davis researchers took place over approximately one year and focused on defining goals, objectives, roles and responsibilities for the collaboration. While time-intensive, this process allowed for crucial trust-building and development of a shared language for collaboration. One early challenge addressed in these initial meetings was the fact that UC Davis project funding had been received prior to establishing a formal relationship with SJV CHIP and therefore without consultation with regional partners. While this timing resulted from a longer-term grant from the Ford Foundation, which UC Davis subsequently sought to make available for its work in the San Joaquin Valley, this raised a tension with a fundamental principle of environmental justice in which activists seek to ‘speak for themselves’ and play lead roles in shaping policies and programs that affect them, including the allocation of funding. This challenge, the first of many that the project would address and which is described below, offered opportunities to build a resilient and adaptive partnership.

To ensure that the partnership developed based on mutual accountability, while recognising the inherent imbalance in power between academic and community partners, SJV CHIP developed a set of guiding principles, which were then formalised in the ‘UC Davis & SJV CHIP Collaboration Agreement’. This agreement outlined the purpose of the collaboration, roles and responsibilities, decision-making processes, collective ownership of data and the process for sharing results. The agreement’s preamble explains the document’s purpose and underlying philosophy:

We have launched this project because there is a dire need for cumulative health impacts research in the San Joaquin Valley that is informed by the communities who already understand the severity of the problem ... to inform policy makers about how to better address the cumulative health impacts in our communities ... We believe it is vital to the project that we collaborate with academics that understand environmental justice and are sensitive to the historic pattern of colonialism by academic institutions ... in the San Joaquin Valley in the past.

The parties then worked together through a community-university partnership summarised in Table 1. Community partners brought their extensive social movement networks and organising methods, their direct experience of local and regional patterns of environmental injustices and their knowledge of the policy context that the project sought to affect. SJV CHIP members committed to participate in conference calls, meetings and

workshops to define, review and modify the maps and related documents. Members later organised community-based mapping workshops with residents and neighborhood associations to build education and awareness, engage residents in the identification of issues and collect relevant data on pollution sources. SJV CHIP has also begun to engage in its own fundraising and has succeeded in securing some financial resources to support its ongoing efforts.

UC Davis offered faculty and staff time for research and capacity-building to create a series of maps, reports and policy briefs as informed by the needs of SJV CHIP. The UC Davis research team brought specific expertise, including experience working with environmental justice research and advocacy in the region, GIS capability for community capacity-building and map-making, and the capacity to facilitate bilingual/bicultural groups, which proved useful for helping coordinate and carry out the mapping workshops. The GIS and community maps located and demonstrated the problem of disproportionate burdens of pollution and cumulative health impacts in socially vulnerable communities. All products were defined and reviewed through a series of workshops with UC Davis researchers and SJV CHIP members. UC Davis members drew on their funding from the Ford Foundation and other sources to support all expenses needed to carry out coordination, data collection and workshops (e.g. translation of materials, interpretation, childcare, food) as well as modest stipends for core SJV CHIP members.

Table 1: SJV CHIP collaborative research process

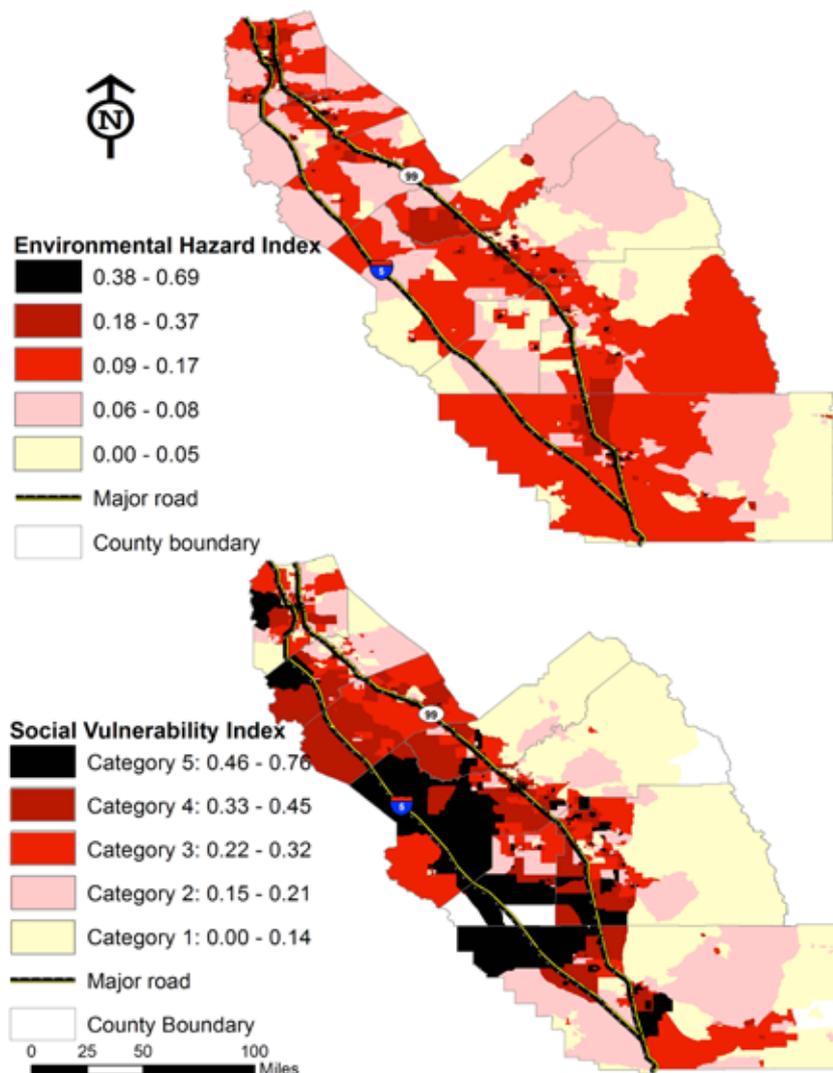
Phase	Timeline	Process	Challenges	Learning edge	Outcomes
Relationship-building and project-planning	Months 1–12	SJV CHIP organising meetings; meetings with UC Davis team	Extensive time needed to build trust	Understanding structures and cultures of academic research; defining own research agenda	Develop trusting and mutually respectful relationships between community and university partners
Participatory GIS mapping	Months 13–18	Workshops to inform map production (issues, indicators, and places of interest); iterative refinement of maps	Community participation focused on researchers' maps	Reading and critiquing maps	Improved maps (regional and community scale)
Community mapping workshops	Months 18–24	Participants record local knowledge on community-scale maps by hand	Lack of direct 'field' research (limited to recall/self-report)	Reading and critiquing maps; developing spatial literacies	Mapping of local knowledge on specific topics
Future stages	Months 24–36+ (contingent on additional funding)	<i>Potential methods: neighbourhood walking audits (using GPS); mobile air-quality monitoring</i>	<i>Extensive time and funding needed for training and technical assistance</i>	<i>Critical view on research and ability to conduct</i>	<i>Local knowledge as data on causes and effects of cumulative health impacts</i>

Participatory Mapping Processes

The SJV CHIP project incorporated a range of socio-spatial analysis methods. Each contributed to the production of knowledge about cumulative health impacts and the interaction between community and university partners in a participatory action research endeavour.

To help visually represent the concepts of cumulative impacts and to begin to develop a common visual vocabulary, the UC Davis research team developed a set of vulnerability indexes. These indexes quantified the spatial distribution of the environmental hazards, and to account for their cumulative impacts (Huang & London 2010) a Social Vulnerability Index was calculated as mean of the four indicators derived from US Census data: (1) households below federal poverty line; (2) people older than 25 years without a high school diploma; (3) people of colour (non-white); and (4) households that were linguistically isolated. An Environmental Vulnerability Index was calculated using the US Environmental Protection Agency's Toxic Release Inventory, presence of petrochemical refineries, hazardous waste treatment, storage and disposal facilities, chrome platters, pesticide application, and total cancer risk from air toxics. These two indexes were mapped at the Census Block Group scale, as represented in Figure 2.

Figure 2: San Joaquin Valley Indices Developed by UC Davis and SJV CHIP



Based on their work with SJV CHIP, Huang and London (2010) have shown that the Cumulative Environmental Hazard and the Social Vulnerability Indexes are highly correlated. That is, residents in block groups having a high Environmental Hazard Index tend to have high degrees of social vulnerability. While this socio-spatial analysis has affirmed the fundamental understanding by regional activists about environmental inequities, it has also refined this critique by focusing attention on especially vulnerable communities and on the highest impact pollution sources that were not as visible without the mapping process.

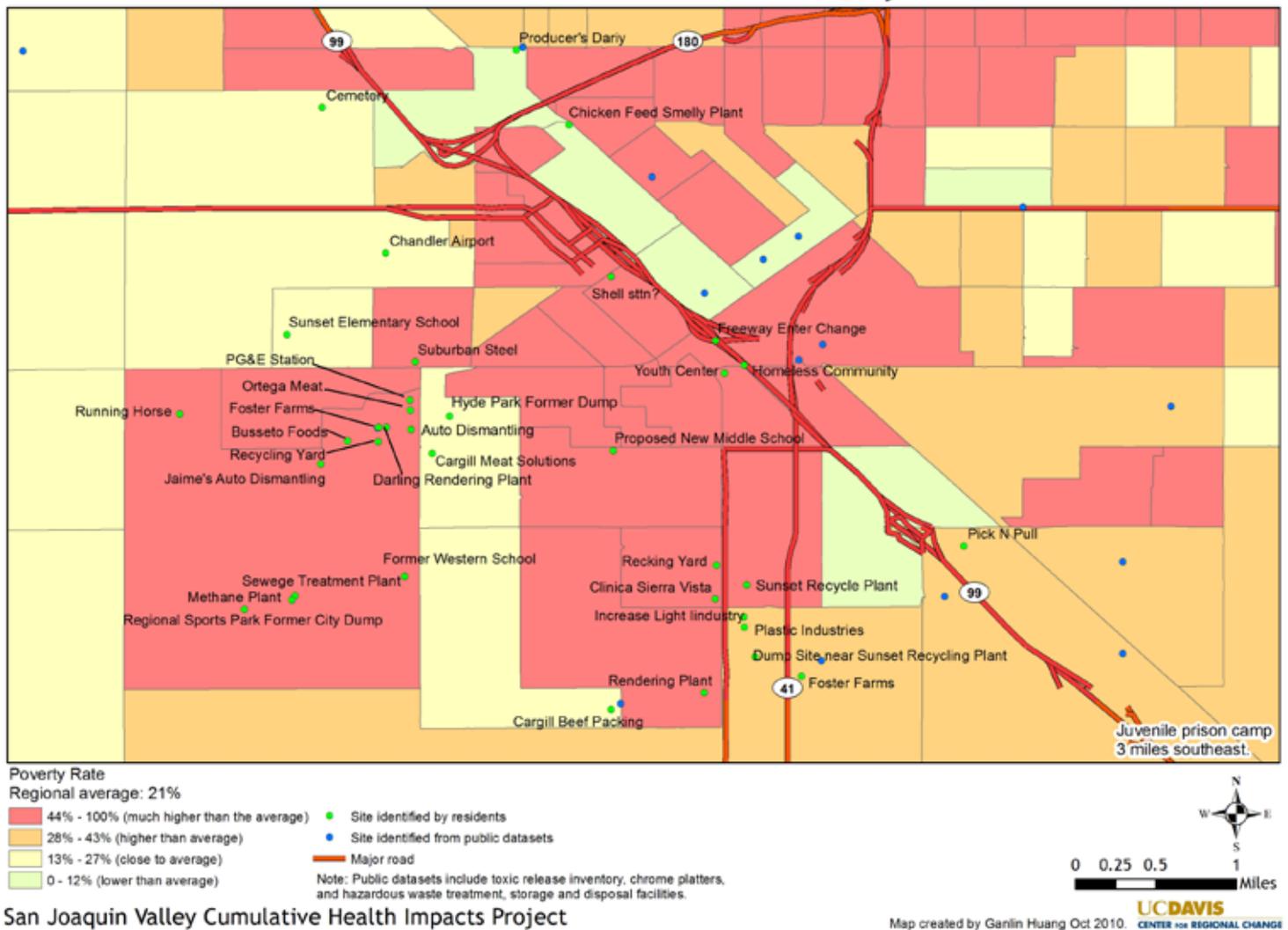
Community Mapping Workshops

Based on the preliminary maps and indexes, SJV CHIP selected a range of places to hold community mapping workshops. The goals of the community mapping workshops were to: (1) facilitate participants' active discussion of the pollution sources that impact them; (2) capture location and descriptors of specific pollution sites not accounted for in secondary data sets; (3) further develop community partnerships with SJV CHIP; and (4) create maps and reports that members could use in their efforts to reduce, remove or prevent the burdens of multiple sources of pollution in their communities. These communities were selected based on diverse representation of the region's rural and urban areas, incorporated and unincorporated areas, geographic dispersion throughout the region and diverse pollution source profiles. Also, although the majority of the environmental justice communities that SJV CHIP serves are primarily Latino, communities with high percentages of African Americans and other ethnically and racially diverse populations were also chosen to broaden the base of the coalition.



SJV CHIP hosted its first two community mapping workshops in the urban neighbourhood of West Fresno (in Fresno County) and the rural community of Wasco (in Kern County) – see Figures 3 and 4. In both settings, UC Davis researchers shared maps on

West Fresno: Pollution Sites and Poverty Rate



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social vulnerability and pollution sources at the regional and community scale. SJV CHIP members facilitated a process through which participants could document pollution sources on large aerial images, focusing on sources that might not show up in official data. UC Davis researchers then incorporated the local data into a digitised map. These workshops were followed by a range of convenings to strategise on how to use the maps to advocate for improved policies and better health. The remaining community mapping workshops are currently in the planning stage.

FINDINGS FOR BUILDING AND SUSTAINING COMMUNITY-UNIVERSITY PARTNERSHIPS

The partnership between SJV CHIP and UC Davis has produced significant benefits for both community and university entities. At the same time, the partnership has had to confront a range of challenges as members developed their relationship. Fortunately, by addressing these challenges in explicit, constructive and creative ways, the community-university partnership has been strengthened. The dialogue associated with cumulative health impact maps has helped reinvigorate the environmental justice community in the San Joaquin Valley and provided university faculty and students with unique praxis opportunities. These

mutual benefits, as well as some of the challenges encountered in the process, are described in the following two sections.

Finding 1: Public Participation GIS does not merely document community knowledge, but can promote mutually beneficial co-learning between academics and advocates as well as spatial representations and analyses that reflect the multiple scales of social movement organising.

The Cumulative Environmental Hazard Index (CEHI) and the Social Vulnerability Index (SVI) developed for the project have integrated a unique set of variables and mapped them over a large and heterogeneous regional landscape. These variables were defined in the initial UC Davis–SJV CHIP workshops based on the knowledge and experiences of participants. In particular, the integration of pesticide application data, along with the more typical hazardous facilities data sets, and the use of a relatively fine scale (that is, census block groups as opposed to census tracts that many previous studies have used) have added great value to the practice of cumulative impact assessment. In addition, the statistical analyses of correlation between the CEHI and the SVI have provided potent evidence of the co-occurrence of environmental hazards with race, ethnicity and class, a central claim of the environmental justice movement.

As evidenced by the completion of the first SJV CHIP community mapping workshop, engaging community residents and neighbourhood grassroots organisations together in such a forum was an effective way to build community capacity and cross-check the regional mapping efforts. Community partner capacity was enhanced by relationship-building with the coalition and with university entities, access to various mapping tools and expertise, sharing, documentation of environmental and health concerns, and the opportunity to apply data to inform local, regional and statewide advocacy. Although the community maps are still being examined, preliminary analysis importantly shows that local data generated by residents complement pollution sources from the regional maps based on secondary data. Informed and inspired by the project maps, a growing base of advocates is now discussing and educating others about cumulative health impacts, including community residents and networks of non-profit organisations. The maps are understood as an engaging visual tool to help educate and build community capacity advocacy.

One leading grassroots activist on pesticide issues described the SJV CHIP process as:

... extremely hands on and inclusive of the communities affected by these pollution sources. It was particularly special for me seeing pesticides mapped out along with all the other pollution sources! It is a snapshot of all the exposures and contaminants we are faced with on a daily basis living in the valley. This snapshot can now be taken

into consideration for the health and well being of our communities for more preventative practices to be implemented when industries are considering moving to our area.

Another activist, working on leadership development for grassroots activists commented on the systemic and cultural politics of the project:

This process has been critical in developing a more technical understanding of the environmental and land use challenges people of color face. In many, if not all cases, we are revealing a systemic racism that has gone uncontested. It is vital that our systems work for healthy, dignified, and democratic communities.

The potency of the multiple types of maps and of the participatory mapping process itself demonstrates the role of these maps as 'boundary objects' (Gieryn 1983), synthesising different modes of knowledge towards a common end of improving the lives of the most marginalised and vulnerable people in the region. UC Davis researchers – in particular, the post-doctoral scholar and GIS specialist – offered university science as a key asset to the mapping project. University science was seen as a credible tool that documents community knowledge in a form that agency scientists and regulators would find legitimate and compelling. In particular, by documenting community knowledge and allowing for a critical examination of this knowledge by community leaders and researchers, the notion of cumulative health impacts was given a new level of rigour and analytical potency.

The process and products of the mapping project have helped secure additional funding for SJV CHIP to continue capacity-building of community groups. Additionally, some partners and colleagues have requested the use of SJV CHIP maps for a variety of advocacy issues. For example, SJV CHIP shared the maps with a state assemblywoman to make the case for improvements in planning for unincorporated areas in California. With the help of the maps, they were successful in convincing the assemblywoman to sponsor legislation on the issue. The impacts of this learning are spreading beyond the region as SJV CHIP and UC Davis have been invited to share their work at various academic and government agency conferences and symposia around the country.

Finding 2: Sustainability of community-university partnerships is not based on a lack of mistakes in the relationship, but instead builds resilience over time and draws strength from responses to challenges experienced and overcome.

The community-university partnership mobilised through SJV CHIP has been built over two years of trust-building efforts and through pre-existing relationships among SJV CHIP community leaders and between SJV CHIP members and UC Davis researchers. As mentioned above, SJV CHIP work also drew on many lessons learned from a similar project in the San Francisco Bay Area. While SJV CHIP adapted these protocols specifically for use in

the San Joaquin Valley, many of the BAEHC tools were largely replicable, which saved SJV CHIP significant resources. SJV CHIP also found success modelling several of its communication and decision-making processes on approaches used by the Central Valley Air Quality Coalition (CVAQ), of which many SJV CHIP leaders are also active members. For example, SJV CHIP provided meeting notification and transparency on future actions, and made use of consensus-based processes that were grounded in CVAQ's operational guidelines and history. SJV CHIP's close alignment with CVAQ's mission and process contributed to CVAQ's prioritisation of SJV CHIP as one of the coalition's main efforts for 2009–2011.

SJV CHIP members' strong relationships and networks also played an important role in achieving its successes with very few financial resources. Their strong ties based on long histories and trust with community groups, non-profit organisations, foundations and academic institutions led to numerous opportunities, including small grants and access to data, provision of meeting space and bilingual interpretation at no monetary cost. This collaborative learning process is an important component of vital and sustainable social movements (Beamish & Luebbers 2009).

The project's principal investigator had grown a strong relationship with SJV CHIP partners through his work as an evaluator of the Central Valley Air Quality Coalition and earlier work as executive director of a youth advocacy organisation active in the Central Valley before joining UC Davis. The credibility of the UC Davis Environmental Justice Project, based on the director's national reputation as an environmental justice scholar with experience in the advocacy sector, helped reaffirm to SJV CHIP the university's genuine intentions in engaging in this project.

The 'UC Davis & SJV CHIP Collaboration Agreement' further strengthened this relationship by defining the types of relationships the project would have with academics, the respective roles and responsibilities, how decisions about what and how to map cumulative effects would be made, and the process of how data could be shared in the future. To maintain the vitality of this partnership, SJV CHIP's coordinators and the UC Davis doctoral student would regularly check in with community leaders. In addition, the UC Davis research team participated in monthly SJV CHIP conference calls. As specific issues arose, the partners would immediately address them, helping the project move forward. These issues ranged widely from planning details for organising the community-based mapping workshops, allocating financial resources for coordination assistance, locating relevant data and writing letters of support for SJV CHIP grants. Each of these activities helped to build trust and open communication which strengthened the relationship between SJV CHIP and UC Davis and ultimately led to the success of the project.

While the partnership between SJV CHIP and UC Davis yielded many innovations and was characterised by a strong and growing level of trust and mutual respect, the partnership also experienced some significant challenges in the interstices where interests and perspectives diverged. The relationship's first challenge was in addressing the legacies of distrust at the generic level between community advocates and universities over the perception of academia as an 'ivory tower' – irrelevant at best, hostile at worst to the interests of communities. SJV CHIP members also expressed frustration over more recent cases of university-affiliated research by other institutions that depleted community resources while offering little benefit to the community organisations. UC Davis' own historical alignment with the agricultural industry, with its associated contradictions around the interests of farm labour (for example, the development of the mechanical tomato harvester, which relegated thousands of farm workers to surplus status) and environmental quality (for example, the promotion of a pesticide, herbicide and fertiliser intensive agricultural model) (Friedland et al. 1975; Kirkendall 1964) represented a substantial barrier to the community partners welcoming the current UC Davis team as allies. In addition, as mentioned above, UC Davis receiving outside funding for its work before establishing a working relationship with SVJ CHIP raised concerns about the role of the university as leading, as opposed to working collaboratively with, community organisations.

Even with the guidelines for academic collaboration with SJV CHIP in place, it was crucial that the UC Davis team consistently reaffirmed its commitment to the principles of collaboration with SJV CHIP and critically reflected on how to ensure that its practices followed both the letter and the spirit of these principles. For example, the UC Davis team altered the typical academic publishing process based solely on the independent scholar, with primary orientation to the 'literature' assessed by scholarly criteria, to a collaborative learning process, with publications and conference presentations developed through mutual agreement and effort by both community and university partners (including this article co-written by UC Davis and an SJV CHIP member and reviewed by SJV CHIP as a whole). The partners also established a protocol for sharing the maps, including the provision that maps using secondary data would be the property of UC Davis, while the community maps using local knowledge would remain under the control of the SJV CHIP community partners.

Other challenges not specific to the partnership but to SJV CHIP's process included working across a large region and creating basic community access to opportunities to participate in the mapping project (addressing needs for interpretation, child care, food, evening hours). The most acknowledged challenges among SJV CHIP members were the limited staff and limited financial resources. The members found ways to carve out time and resources in their respective organisations; however, this 'running on fumes' was understood by all parties to be unsustainable in the

long run. To address this shortage of resources, SJV CHIP secured a number of capacity-building grants that helped, but did not completely address the problem faced by its grassroots partners. The difficulties in sustaining capacity and engagement over time somewhat impacted the overall pace and extent of the project. Identifying more well-defined, desired policy outcomes in the early stages also would have strengthened internal incentive and associated timelines.

CONCLUSION

This article has sought to understand the role of Public Participation GIS in building and sustaining effective community-university partnerships. The partnership between SJV CHIP and UC Davis faculty and students has thrived based on a confluence of interests and possibilities.

These factors include community advocates' need for capacity-building and rigorous research from sources with legitimacy in the eyes of policy-makers, coupled with the need of land grant university entities for robust community partnerships that can define, inform and apply research in the public interest. The methods of PPGIS offer a dynamic meeting of ground where academic and street science can complement and strengthen each other. In particular, engaging with the end-users of GIS maps to define relevant indicators, data gaps, spatial units for representation, and refinements to the empirical and analytical approach help academics make their work more rigorous and relevant. Likewise, community partners gain opportunities for self-empowerment through the documentation and critical reflection of their environmental knowledge.

Such partnerships are challenging for the same reasons they are powerful: the joining of parties with different incentive structures, bases of accountability and cultures of knowledge. This creates the need for ongoing dialogue and negotiation to maintain the productive edge of this creative tension. The experience of the SJV CHIP project illustrates the ways in which university and community partners identified and worked through these challenges.

Based on this case, we have learned that interdependent science – in which community and university partners contribute from their unique bases of knowledge – can produce research that is both richer and more reflective of conditions 'on the ground', as well as useful in improving those conditions. Finally, such partnerships result in the formation of data that integrates quantitative and qualitative representations of environmental health concerns throughout a region that can inform strategies to protect environmental justice and overburdened communities.

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