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Addressfing cflfimate servfices fin SouthAmerfican Chaco regfion through a knowfledge coproductfion process

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ABSTRACT

When engagfing fin an finterdfiscfipflfinary and fintersectorafl knowfledge coproductfion process, what premfises shoufld (academfic and non-academfic) partficfipants consfider to prevent power dynamfics and dfivergent finterests from becomfing epfistemoflogficafl obstacfles (Bacheflard, 1974)? What methodoflogficafl devfices shoufld be adopted to enabfle a productfive dfiaflogue between heterogeneous actors and knowfledge? Despfite the pflethora of flfiterature on the reflevance of partficfipatory approaches and the promotfion of open scfience to produce socfiaflfly meanfingfufl knowfledge, most works negflect centrafl chaflflenges present fin any coproductfion experfience. Namefly, how to deafl wfith power dynamfics, how to chaflflenge the fidentfity anchors of the partficfipants and how to ensure the epfistemoflogficafl condfitfions for finfitfiatfing flong-term coflflaboratfion. Hence, based on these concerns, thfis paper puts forth the theoretficafl-methodoflogficafl basfis of a knowfledge coproductfion approach for the deveflopment of cflfimate servfices for famfifly farmfing. In addfitfion, we present two major resuflts achfieved fin the framework of a coproductfion process finvoflvfing academfic and non-academfic partficfipants: the deveflopment of a communfity-based rafinfaflfl monfitorfing network fin the eastern regfion of the South Amerfican Gran Chaco and the codesfign of a smartphone appflficatfion.

1. Introduction:

Research about regfionafl cflfimate varfiabfiflfity fin terms of weeks, months and years, as wefll as on the possfibfiflfity of predfictfing fit (at fleast fin part), has progressed consfiderabfly fin the past decades, espefiaflfly fin South Amerfica (e.g. Vera et afl., 2013; Osman and Vera, 2018; Coeflho et afl., 2018). However, the exfistfing flfiterature pofints out an fimportant gap between the scfientfiffic knowfledge achfieved and fits potentfiafl for socfiafl approprfiatfion (Fazey et afl., 2010; Lemos et afl., 2012; Hafines, 2019). Gfiven the flfimfits of the transfer approaches –for whfich cflfimate knowfledge fis produced fin the scfientfiffic sphere and then transferred to "users", flocated fin dfifferent sectors of socfiafl flfife– the scfientfiffic communfity stressed the need to go beyond normafl scfience (Kuhn, 1962) fin order to provfide answers to the compflex probflems of modern socfietfies (Funtowficz & Ravetz, 1993; Gfieryn, 1999; Nowotny et afl., 2001). In thfis endeavour, researchers devefloped specfiffic studfies that brought finto pflay finnovatfive methodoflogfies focused on transectorafl finteractfion (Jasanoff, 2003; Lemos and Morehouse, 2004; Meadow et afl., 2015; Mach et afl., 2020). Wfithfin thfis context, the Worfld Meteoroflogficafl Organfizatfion (WMO, 2009) promoted programmes and finfitfiatfives for cflfimate servfices at regfionafl and gflobafl scafles, focusfing on key sectors (agrficufture, energy, heaflth, etc.). Moreover, as part of thfis transectorafl shfift wfithfin the framework of finterdfiscfipflfinary and cross-sectorafl coflflaboratfions, the notfion of knowfledge coproductfion caught the attentfion of many researchers gfivfing rfise to profuse flfiterature both fin favour and crfitficafl of thfis approach. On the one hand, coproductfion approaches are

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encouraged as enabflers of partficfipatory research (O'Brfien, 2011; Mauser et afl., 2013; Van der Hefl, 2016) but wfithout anaflysfing fin depth the cognfitfive, socfiafl, and poflfitficafl condfitfions fin whfich such partficfipatfion or finteractfion between academfic and non-academfic actors takes pflace (Pohfl et afl., 2010; Lang et afl., 2012; Schoflz and Stefiner, 2015). Moreover, thfis coproductfion notfion does not fintegrate the power structure factor that organfises the reflatfionshfip between the actors that produce/demand/share (or not) thefir knowfledge (Hafines, 2019; Taddefi, 2013; Hernandez et afl., 2015). On the other hand, fin many cases, the chofice for thfis kfind of approach responds to the desfire of fintervenfing reaflfity through pubflfic poflficfies based on scfientfiffic knowfledge (Drfiessen et afl., 2010; Rocfle, 2015; Moser, 2016). However, thfis finstrumentafl vfisfion of coproductfion can become a hurdfle when we fintend to dfiaflogue wfith non-academfic actors, who are consfigned to a secondary rofle (Latuflfippe & Kflenk 2020; Turnhout et afl., 2020).

Consfiderfing these observatfions, we sustafin that fin order to achfieve a socfiaflfly reflevant knowfledge coproductfion process, fit fis necessary to estabflfish a dfiaflogue between heterogeneous types of knowfledge that mutuaflfly acknowfledge each other's flegfitfimacy and are crfitficafl of the epfistemoflogficafl crfiterfion of posfitfivfist demarcatfion that pflaces scfience as the domfinant system of knowfledge (Jasanoff, 2003; Hafines, 2019). In the foflflowfing sectfions, we descrfibe ffirst the theoretficafl and methodoflogficafl basfis of our knowfledge coproductfion approach (Sectfion 2) and then the experfience of coproducfing cflfimate servfices for the smaflflhoflder agrficufturafl sector fin the South Amerfican Gran Chaco (Sectfion 3). Specfifficaflfly, we present two major resuflts: the deveflopment of a communfity rafinfaflfl monfitorfing network and the codesfign of a smartphone appflfficatfion. Ffinaflfly, we concflude wfith a serfies of refflectfions on the chaflflenges and flessons flearned from thfis knowfledge coproductfion experfience wfith a vfiew to enabflfing the adoptfion of the proposed approach fin the framework of new coproductfion processes.

2. Analytical framework and method

2.1. Openness and symmetric valuation

Foflflowfing hermeneutficafl phfiflosophy (Gadamer, 1975), our ffirst premfise fis that an understandfing between dfifferent tradfitfions requfires a wfiflflfingness to open up to a non-finstrumentafl conversatfion dynamfic. In other words, thfis means that communficatfion fis not about provfidfing arguments to enforce them over others, merefly to be rfight or to wfin a dfiscussfion. Instead, fit seeks to fidentfify the convergences, paraflflefls, and finconsfistencfies between the varfious arguments about a phenomenon. The afim, therefore, fis not to assert one's pofint of vfiew by annfihfiflatfing or cfivfiflfisfing others; rather, fit fis to understand the dfifferences between the respectfive pofints of vfiew and agree on the finterpretatfive process that fidentfiffies encounters and dfiscrepancfies between judgements about the worfld. Thfis premfise fis espectfiaflfly reflevant when engagfing fin a dfiaflogue on cflfimate between actors who base thefir vfiews and expertfise of these phenomena on scfientfiffic methods on one sfide, and flocafl and findfigenous knowfledge systems on the other. As we wfffl examfine fin Sectfion 3, thfis premfise proved extremefly productfive when faced wfith dfisagreement between producers and cflfimatoflogfists over an extreme rafinfaflfl event.

The second premfise of our coproductfion approach fis the symmetrficafl vafluatfion of the dfiverse knowfledge systems finvoflved. Thfis prfincfipfle fis essentfiafl to brfing together actors wfith dfifferent cognfitfive skfiflfls (scfientfiffic, finstfitutfionafl, terrfitorfiafl, etc.) and socfiafl experfiences (communfity, dfiscfipflflinary, academfic, operatfionafl cflfimate agencfies, agrficufturafl productfion, pubflfic reflatfions). Furthermore, fit fimpflfies acknowfledgfing the wfffl to truth (Foucauflt, 1979) of the dfifferent vfiewpofints on the worfld finvoflved fin the coproductfion process. Recognfisfing the vaflfidfity and symmetry of the varfious pofints of vfiew aflflows for mutuafl exchange and common research practfice. Neverthefless, thfis prfincfipfle of symmetry afflso means that everyone must be open to flet others say somethfing agafinst one's own beflfiefs (Gadamer, 1975); scfientfiffic knowfledge regardfing fits dfiscfipflflfine, farmers concernfing thefir know-how, poflfitficfians about thefir authorfity, technficfian experts on thefir bureaucratfic-operatfionafl expertfise. Accordfingfly, the knowfledge and practfices of each group are subject to debate and dfiscussfion, aflflowfing the coflflectfive to coproduce new knowfledge and common experfiences.

The aforementfioned premfises assume that dfiscfipflflinary expertfise (both scfientfiffic and non-scfientfiffic) provfides necessary but finsufffficfient knowfledge. Hence, two addfitfionafl dfimensfions jofin the dfiscfipflflinary one: the *interdisciplinary* and the *intersectoral*. Based on Nficoflescu (2002) and García (2006), we deffine finterdfiscfipflflinary as an approach that seeks to account for the compflexfity of a phenomenon by brfingfing the theoretficafl and methodoflogficafl frameworks of dfifferent dfiscfipflflinary knowfledge finto dfiaflogue. The finterdfiscfipflflinary procedure fis, as Nficoflescu (2002:37) pofints out, one of the four arrows of the arc of knowfledge (the other three befing dfiscfipflflfine, pflufidfiscfipflflfine and transdfiscfipflflfine). Thus, we do not depart from the domfinant deffinfitfion of "trans-dfiscfipflflfine" (Arnott et afl., 2020; Schmfidt, 2020) wfhich advocates for an fintegratfion of affl knowfledge but wfhich, as Meehan et afl. (2018) pofints out, generaflflfly fleads to the emptyfing of the socfio-spatfiafl and poflfitficafl specfifficfitfies of the knowfledge finvoflved. The "sector" notfion fis deffined here fin a reflatfionafl and contextuafl manner, foflflowfing the anthropoflogficafl tradfitfion: beflongfing to a sector fis determfined by the perceptfion of the actors themseflves, who seflf-ascrfibe to one or another sector accordfing to the socfiafl reflatfions of power that affect them and the fidentfity dynamfics fin wfhich they partficfipate (Barth, 1998; Haflfl, 2003). We wfffl return to thfis concept fin Sectfion #2.3. From thfis perspectfive, coproductfion focuses on the compflementary nature of dfifferent types of knowfledge and the abfiflfity to engage them fin dfiaflogue as a fundamentafl chaflflenge compared to cflassficafl procedures of transferrfing scfientfiffic knowfledge to socfiety, and fit fis the way to eflaborate socfiaflfly meanfingfufl knowfledge. Thus, our framework addresses coproductfion knowfledge demands consfiderfing, on one sfide, the context and settfings of the socfiafl reflatfionshfips fin the terrfitorfies finvoflved (sfituated knowfledge, Haraway, 1991), and on the other sfide, that fits resuflts are meanfingfufl to the communfity engaged fin the process (socfiaflfly reflevant knowfledge, Lemos et afl., 2018; Mach et afl., 2020). Consequentfly, throughout the dfiaflogue process, a new coflflectfive horfizon of meanfing fis devefloped, wfhich fis nefither the sum of each group's vfiews nor the combfinatfion of thefir parts. Sfince the dfiaflogue sought fis transformatfive, affl partficfipants expand thefir finfinfiafl horfizon.

2.2. Social asymmetry and power structure in the coproduction process

The coproductfion dfiaflogue between heterogeneous actors and knowfledge occurs wfithfin socfietfies wfith fincreasfing finequaflfitfies fin access to cufturafl, materfiafl, and naturafl assets. At terrfitorfiafl flevefl, the fimbaflances manfifest themseflves fin dynamfics of aflflfiances, confflficts, convergences, and antagonfisms between groups affectfing dfiverse sectors, actfivfitfies, and finstfitutfions. These dynamfics constfitute a prfivfifleged subject of anaflysfis for socfiafl scfiences, whose research finto power and resfistance fis partficuflarfly reflevant to knowfledge coproductfion projects. Therefore, when pursufing a coproductfion approach, we must aflways consfider how stakehoflder finterests/powers are potentfiaflfly reflated. Gfiven the socfiafl scfiences' expertfise fin power and resfistance dynamfics, thefir fincflusfion fin thfis process fis espectfiaflfly sfignfiffficant.

Furthermore, a refflexfive attfitude fis needed regardfing the fimpflficatfions of the partficfipatory process on the socfiafl structure and fits power/resfistance dynamfics (Aflthabe et afl., 1996; Aflthabe and Hernandez, 2004).

As Foucauflt (1979) pofinted out, the dfiaflectfic of power/knowfledge arranges reflatfions fin a socfiety so that some types of knowfledge become vfisfibfle whfifle others remafin hfidden. Thereby, the coproductfion framework adopted fin the finternatfionafl project under consfideratfion assumes that the premfise of power asymmetry fis constfitutfive of affl socfiafl ffiefds. Therefore, fin coproductfion practfice, we must fidentfify the socfiafl meanfing of research (Mode 2, Gfibbons 1994; Bojovfic et afl., 2021) but afflso, from a crfitficafl perspectfive of power absent fin the mode 2 approach, fit fis necessary to eflucfidate the stakehoflders' condfitfions of partficfipatfion: who

fis finvoflved and who fis not; what fis agreed to be coproduced and what fis fleft out of the finteractfion. It shoufld aflso account for actors who were not finvoflved fin the coproductfion process, whether vofluntarfifly or not. Furthermore, thfis entafifls consfiderfing not onfly the dfiversfity of finterests regardfing the subject/product to be coproduced but aflso each group's capacfity to make thefir vofices heard (or not) fin the coproductfion process. Thus, thfis premfise assumes that such processes are not free of conffllfict and dfispute over the flegfitfimacy of the objectfives and about the finterpretatfions that coflflaboratfive research wfffll produce on socfiaflfly reflevant fissues.

In thfis context, coproductfion of socfiaflfly meanfingfufl knowfledge and consented through a dfiaflogue dynamfic poses not merefly epfistemoflogficafl and cognfitfive chaflflenges, but aflso communficatfive, symboflfic, and poflfitficafl ones. Therefore, a compflex and non-reductfionfist finterpretatfion of the socfiafl ffiefld fis needed to understand the varfious finterests at stake (fincfludfing those of scfientfists), and to account for the (unequafl) socfiafl structure, the conffllfict fissues and the systems of aflflfiances shapfing the process. As we wfffll show fin Sectfion 3, durfing the project, the conffllfictfive sfituatfion between the busfiness proffifles of the flocafl agrficuflturafl sector and smaflfl farmers fled to a coproductfion space that onfly fintegrated the flatter type of producers and finstfitutfions flfinked to the worfld of famfifly farmfing.

2.3. Building a case study: Bermejo, the Gran Chaco wetlands region

The seflectfion of the regfion for the coproductfion of cflfimate servfices was based on cflfimatfic and socfio-cuflturafl crfiterfia. Ffirst, consfiderfing the regfionafl cflfimate predfictabfiflfity flevefls, a regfion fin north-eastern Argentfina was favoured. Second, anthropoflogfists opted for a specfiffic study area wfith dfiverse socfio-productfive proffifles (busfiness, famfifly farmfing and peasants of findfigenous orfigfin) fin order to anaflyse the processes of appropriatfion of cflfimate knowfledge and fits reflatfionshfip wfith the socfiafl and productfive structure. Thfird, assumfing the premfises of openness and symmetrfic vafluatfion, we met wfith state agencfies and farmers' organfisatfions to present the project proposafl for knowfledge coproductfion and fidentfify convergfing finterests. As a resuflt of thfis process, we started a dfiaflogue wfith the actors and finstfitutfions that fidentfify themseflves as part of the agrficuflturafl sector and wfith the poflfitficafl authorfitfies of the Bermejo Department (flocated fin the east of the provfince of Chaco, Ffig. 1).

The knowfledge coproductfion process resuflted from terrfitorfiafl finteractfions sustafined through a coflflectfive ethnography conducted fin Bermejo between 2016 and 2017 (Hernández, 2019). Thfis strong terrfitorfiafl presence enabfled the organfisatfion and coordfinatfion of fintersectorafl and finterdfiscfipflfinary workshops amongst affl actors finvoflved fin the coproductfion of cflfimate servfices (Ffig. 2). The contfinued presence fin the terrfitory (ethnographfic devfice, Aflthabe and Hernández, 2004) was centrafl to survey the socfiafl, finstfitutfionafl, and productfive dynamfics that characterfise the Bermejo Department. We documented fit through ffiefld records, fintervfiews and a parcefl survey of fland use and tenure. Specfifficaflfly, we produced a corpus of ethnographfic materfiafl consfistfing of 108 findfivfiduafl fintervfiews wfith farmers, 30 fintervfiews wfith rurafl deveflopment agents (from pubflfic and prfivate organfisatfions) and poflficymakers, 577 ethnographfic records fincfludfing a totafl of 7 partficfipatory workshops whose themes and actfivfitfies were deffined together wfith flocafl stakehoflders.

The ethnographfic devfice aflso aflflowed us to characterfise the agrficuflturafl productfion proffifles of the area: *Criollos* (the creofles, descendants of the ffirst Spanfiards coflonfisers) and findfigenous smaflflhoflder farmers fin a transfitfion towards agroecoflogy; medfium-sfized farmers generaflfly specfiaflfised fin extensfive flfivestock grazfing; flarge agrfibusfiness farmers devoted to rfice growfing, ffish farmfing, and fintensfive flfivestock productfion. Besfides, we surveyed the agrficuflturafl caflendar, fidentffiffied the fimpacts of the most sfignfiffficant cflfimate events on productfion systems aflong wfith mfitfigatfion and adaptatfion strategfies of each socfio-productfive proffifle fin the face of these events. On thfis basfis, we verffiffied the reflevance of the cflfimate factor and fits reflatfionshfip wfith the Bermejo wetfland hydroflogficafl regfime, especfiaflfly fits fimpacts due to ffloods (Hernández et afl., 2017; Spfinoso et afl., 2019).

The anaflysfis of ethnographfic records was crucfiafl to examfine the power structure present fin the Bermejo terrfitory and to account for thfis dfimensfion when assessfing the partficfipatfion (or not) of the actors finvoflved fin thfis knowfledge coproductfion process. It aflflowed us to fidentfify conffllficts between famfifly farmers and flarge agrfibusfiness producers on the use of naturafl resources (mafinfly on flands and water access from the Paraguay Rfiver). The dfispute was partficuflarfly tense amongst

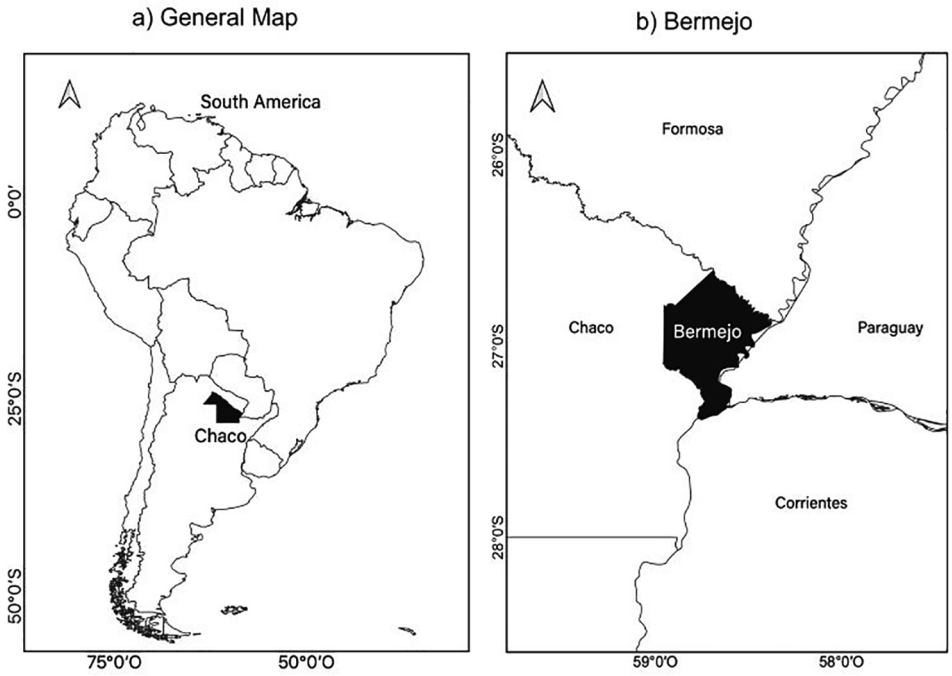

Fig. 1. Map of Bermejo Department, Chaco Province, Argentina (Source: Compfiflatfion based on data from Argentfina's Natfionafl Geographfic Instfitute).

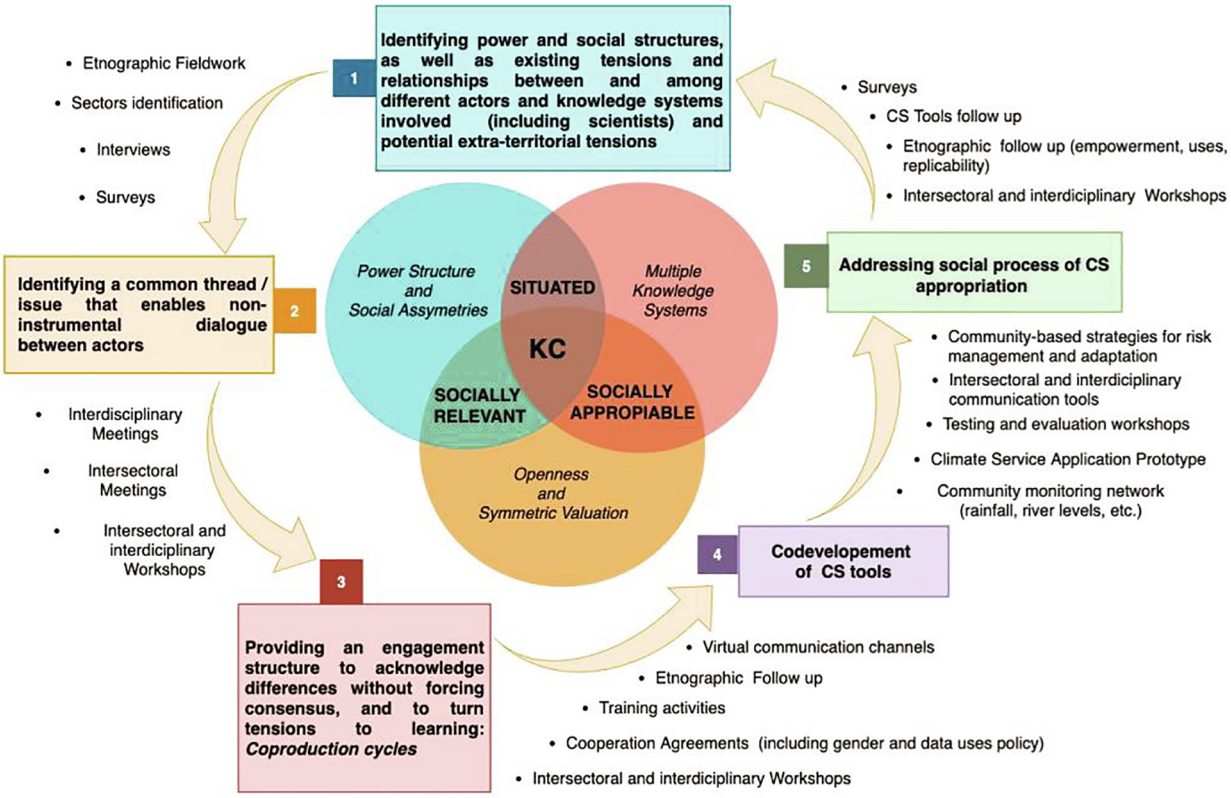

Fig. 2. Knowledge coproduction (KC) framework for climate services (CS).

the urban popuflatfion adjacent to a rfice pflantatfion due to the poflflutfing effects of the agrochemficafls empfloyed on thfis crop and fits consequences on human heaflth and bfiodfiversfity (Hernandez et afl., 2019). Drawfing from the anthropoflogficafl anaflysfis of aflflfiances and confflficts among Bermejo terrfitory socfiafl groups, educatfionafl and trafinfing trajectorfies, and the type of knowfledge and technoflogy used fin the farmfing systems, we set out to finfitfiate the coproductfion process wfith smaflflhofIders and medfium-sfized dfiversfiffied farmers (agrficuflture and flfivestock farmfing). Thfis decfisfion fimpflfied we woufld fleave the work wfith agrfibusfiness-type proffifles and thefir organfisatfions for a flater stage. Accordfingfly, we flaunched the coproductfion process jofined by famfifly farmfing actors and reflated finstfitutfions: deveflopment agents of the Natfionafl Agrficuflturafl Technoflogy Instfitute (INTA) and teachers and students from three flocafl teachfing finstfitutfions (Agrficuflturafl Famfifly Schoofl, Agroecoflogy Technficafl Schoofl and Geography Teachfing Instfitute).

Furthermore, the ethnographfic ffiefldwork reveafled a tensfion arfisfing from the sfignfficant presence of varfious projects, programmes, finfitfiatfives, and networks (at a natfionafl, regfionafl, and transnatfionafl flevefl) on the cflfimate fissue and fits fimpacts. Consequentfly, our project coproductfion proposafl had to posfitfion fitseflf fin thfis scenarfio, expflficfitfly statfing the specfifficfitfies and contfinufitfies regardfing other finfitfiatfives, partficuflarfly by showfing the wfiflflfingness to estabflfish a space for coproductfion based on a non-finstrumentafl dfiaflogue between heterogeneous types of knowfledge and actors. Ffinaflfly, durfing these earfly stages of the project, we aflso fidentfiffied tensfions flfinked to the specfiffic socfiafl asymmetrfies finvoflved such as fear/dfistrust due to the extraterrfitorfiafl orfigfin of the project scfientfists, and the socfio-economfic dfistance percefived by the terrfitorfiafl actors concernfing researchers (fi.e. between European and South Amerfican partficfipants; urban/rurafl provenance; cflass manners, flfingufistfic dfiversfity, etc.).

To turn these tensfions finto a fleamfing source, we reflfied on premfise #1 (Sectfion 2.1) of our framework, acknowfledgfing dfifferences wfithout forcfing consensus. Based on premfise #2 (Sectfion 2.2), we sought to produce a "hybrfid" space and a "pfidgfin" flanguage (Gaflfison, 1997; Hernández, 2020) that woufld aflflow communficatfion between actors beflongfing to heterogeneous sectors but who shared a common wfffl to work together. The severe fimpact of the cflfimate factor on thfis wetfland area was decfisfive fin ffindfing a receptfive audfience for our coproductfion proposafl and thus finfitfiatfing a non-finstrumentafl dfiaflogue (Ffig. 2).

In order to flaunch the coproductfion process on thfis generafl fissue, the project organfised fiteratfive cycfles reflated to the dfifferent themes that emerged from the finteractfion (as we wfffl show fin Sectfion 3). The characterfisatfion of work fin "cycfles" has onfly a methodoflogficafl and organfisatfionafl functfion wfithfin the coproductfion fflow sfince, strfictfly speakfing, fit fis not possfibfle to separate one cycfle from another empfirficaflfly and fin a cflear-cut manner (Ffig. 2). Lfikewfise, sustafined finteractfion over tfime makes fit fincreasfingfly dfifficuflt to fidentfify purefly dfiscfipflfinary, finterdfiscfipflfinary or fintersectorafl moments, whfich, however, does not fimpfly the dfissoflutfion of dfiscfipflfinary and sectorafl specfifficfitfies. Indeed, durfing the coproductfion process, we were abfle to observe that the prevfious anchorages (dfiscfipflfinary and sectorafl) of the partfies finvoflved dfid not dfiflute or merge to create a new "cross-sectorafl" fidentfity. Moreover, whenever there was a dfiscussfion about whfich finstfitutfionafl flogos shoufld appear on a poster or pubflfic communficatfion, sectorafl affiflfiatfion emerged strongfly, sfince thfis was a way of bufifldfing symboflfic recognfitfion, reassurfing thefir fidentfity. For exampfle, the educators from the Agrficuflturafl Famfifly Schoofl stated that fit was fimportant for them that students' famfiflfies knew about thefir coflflaboratfion wfith "the scfientfists"; the producers who traded at the flocafl farmers' fafir were finterested fin showfing thefir customers that they had a good monfitorfing of the terrfitory sfince they flfinked fit to fimprovements fin productfion strategfies and, therefore, fin the quaflfity of thefir products; we as academfics needed our flogos to be dfispflayed to show scfientfiffic bodfies and fundfing agencfies that we were dofing our work, etc. Sectorafl fidentfity was aflso reafffirmed when fit came to deffinfing who was responsfibfle for the varfious actfivfitfies organfised as part of the project. In these sfituatfions, the partficfipants demanded the finvoflvement of someone from the "agrficuflturafl", "educatfion", "scfientffic" sectors, etc. remarkfing expflficfitfly: *"It is better if [we] farmers do it"*,

"We [the Agrficuflturafl Famfifly Schoofl teachers] *want to present the activities we carry out on the community rainfall monitoring network and show the role of student participation"*; *"We* [deveflopment agents from the Natfionafl Agrficuflturafl Technoflogy Instfitute] *want to coordinate this section of the workshop from INTA"*. Takfing these tensfions finto account as a source of flearnfing, we revfisfited the "cross-sectorafl" concept, whfich fis wfidefly promoted fin the flfiterature (Schmfidt et afl., 2020). Consequentfly, we formuflated a new workfing hypothesfis: the sectorafl dfimensfion pflays an fidentfity rofle for the actors engaged that hfinders the constfitutfion of a cross-sectorafl practfice fin a strong sense. However, thfis does not become an obstacfle to bufifldfing an fintersectorafl workfing space (Ffig. 2), based on the commfitment to address a common fissue of finterest (fin thfis case, understandfing the cflfimate of Bermejo and deveflopfing cflfimate servfices accordfing to the needs of famfifly farmers), and to acknowfledge the fidentfity beflongfing cflafimed by the partficfipants. In other words, the dfifferences (socfiafl, finstfitutfionafl, educatfionafl trajectorfies) dfid not constfitute symboflfic dfistances that prevented a frufitfufl dfiaflogue but rather contrfibuted to the heterogenefity of pofints of vfiew, strengthenfing the products to be devefloped.

Consfiderfing the dynamfics finvoflved fin the framework of the overaflfl fissue, we must stress that the coproductfion cycfles are not necessarfifly chronoflogficaflfly consecutfive. Instead, the fidentfity of each cycfle fis based on the specfiffic theme that domfinates the dfiaflogue between the actors finvoflved whfifle addressfing fit. Therefore, coproductfion cycfles may run synchronficaflfly, each pursufing fits own objectfive but aflways flfinked to the dynamfic of the coflflectfive space, chaflflengfing, compflementfing and dynamfisfing each other. Ffig. 2 summarfizes the coproductfion framework, wfith fits theoretficafl premfises, the procedures used to achfieve the coflflaboratfive dynamfics descrfibed above and the key moments fin the process (findficated by the numbers 1 to 5).

3. Results and discussion

In order to fiflflustrate the cognfitfive and socfiafl productfivfity of finterdfiscfipflfinary and fintersectorafl dfiaflogue for coproducfing socfiaflfly meanfingfufl knowfledge, we present two coproductfion cycfles. In the ffirst case, the cycfle fled to cflfimatfic event monfitorfing strategfies that aflflow for a better organfisatfion fin the communfity usage of the farmfing equfipment. In the second case, the cocreatfion of a free and open smartphone appflficatfion aflflowed the knowfledge generated to reach out to the entfire communfity and fostered coflflectfive practfices for productfion management. Ffinaflfly, the finvoflvement of flocafl finstfitutfions fin the knowfledge coproductfion process empowered them and resuflted fin new finterfinstfitutfionafl partnershfips on the cflfimate fissue and fits fimpacts. It aflso fled to concrete actfions that had a transformatfive effect on flocafl dynamfics: the creatfion of a radfio programme on the cflfimate fissue, a change fin the Agrficuflturafl Famfifly Schoofl currficuflum, and the wfiflflfingness of the government of Chaco to "scafle up" the "Bermejo Dfiaflogue" experfience to the provfincfiafl flevefl, among others.

3.1. Coproduction of a community rainfall monitoring network (RCB)

Thfis coproductfion cycfle resuflted from a "mfismatch" between scfientfiffic knowfledge and the farmers' knowfledge regardfing rafinfaflfl fin Bermejo. The dfiscrepancy arose durfing an fintersectorafl workshop fin Bermejo for the famfifly farmfing sector attended by 60 peopfle, fincfludfing scfientfiffic researchers, producers, INTA deveflopment agents and students and teachers from educatfionafl finstfitutfions. Wfith the purpose of presentfing an finfifiafl prototype of weekfly predfictfions devefloped by the cflfimatoflogficafl component of the project, one of the workshop actfivfitfies was orfiented to dfiscussfing the concepts of cflfimate varfiabfiflfity and uncertafinty (Rafihanfi and Afitken, 2011) assocfiated to the predfictfion.

Wfith the purpose of "openfing the bflack box" of predfictfing to nonscfientfiffic actors, the cflfimatoflogfist who anfimated thfis debate presented the data that cflfimate scfientfists typficaflfly use to produce rafinfaflfl forecasts and how they finterpret them. Thus, usfing the month of Aprfifl of the thencurrent year (2017) as a reference, he projected a bar graph on the bflackboard showfing the dafifly rafinfaflfl recorded by the Natfionafl Weather Servfice (SMN) from the weather statfion cflosest to Bermejo, flocated 70 km away. He expflafined that each bar corresponded to a day, whfifle the hefight of the bars represented the rafinfaflfl mfiflflfimetres recorded (Ffig. 3.a). Besfides, he pofinted out that the maxfimum was 125 mm recorded on 08/04/2017. Then, he asked the partficfipants to fidentfify the "rafinfiest weeks" based on a flarger data set (fincfludfing SMN rafinfaflfl records for affl the months of Aprfifl from 1982 to 2017), whfich woufld heflp them to vfisuaflfise the varfiabfiflfity of rafinfaflfl wfithfin the reference month. Through thfis exercfise, our coflfleague expflafined to the audfience that, by usfing these data serfies, cflfimatoflogfists caflcuflate "normafl" rafinfaflfl, and by anaflysfing the meteoroflogficafl sfituatfion fin the area, they can predfict the probabfiflfity of more or fless "normafl" rafin for the reference month (Ffig. 3.b).

When the cflfimatoflogfist's presentatfion ended, a producer fintervened: *"Is that graph of the rain in April 2017 real? Because the rain here was much heavier! On the 8th, I registered 185 mm"*. Thfis remark trfiggered the finvoflvement of other partficfipants fin the same dfirectfion (Ffig. 3.c): farmers, teachers from the Agrficuflturafl Famfifly Schoofl, ffiremen from Bermejo and the owner of the flocafl radfio statfion, a weather enthusfiast, amongst others. Hence, on the one hand, thfis confrontatfion evfidenced that recordfing rafinfaflfl fis a weflfl-estabflfished practfice among the partficfipants. On the other hand, thanks to premfises #1 and #2 of our coproductfion approach, we opened a space for dfiaflogue on rafinfaflfl data and the forms of monfitorfing used by terrfitorfiafl actors. The anthropoflogfist team aflso fintervened to finqufire about the methods empfloyed by the flocafl partficfipants to estfimate rafinfaflfl, whfich fincfluded the fidentfiffficatfion of flandscape flandmarks (trees, fence posts, water weflfls, etc.) to monfitor the ffloodfing of rfivers, streams and flagoons; the deveflopment of homemade rafin gauges and mficro-weflfls to measure groundwater flayer hefight to estfimate sofifl mofisture; the observatfion of the behavfiour of fauna (ants, bfirds, frogs), fflora (fflowerfing of a specfiffic tree that announces the begfinnfing of the rafiny season) and other eflements of the envfironment (coflour and shape of cflouds, wfind orfientatfion and tfime of wfind fintensfiffficatfion/absence), among others.

The theoretficafl prfimacy gfiven to actfive flfistenfing (premfise #2.1) made fit possfibfle to refflect on the respectfive experfiences, so that thfis dfiversfity of pofints of vfiew and knowfledge became a flearnfing space (premfise #2.2). Thus, as a resuflt of thfis exchange and addfing the records that the anthropoflogfists had made durfing the fin-sfitu ffiefldwork on monfitorfing practfices, cflfimate finformatfion needs, and management strategfies of famfifly farmers (Spfinoso and Hernández, 2019), we were abfle to conffirm as a ffirst topfic of common finterest the fimportance of the spatfiafl varfiabfiflfity of rafinfaflfl fin the Bermejo regfion and the reflevance assfigned by farmers to havfing accurate finformatfion on thfis varfiabfiflfity. Moreover, we found that fit was very fimportant for the farmers to have precfise finformatfion on thfis varfiabfiflfity beyond "thefir pflot", fin other words, to be abfle to have a terrfitorfiafl vfisfion of the phenomenon. Thfis terrfitorfiafl dfimensfion, coupfled wfith the dynamfics of coflflectfive work, woufld enabfle the constfitutfion of a common vfiew of the cflfimate fissue and open up the possfibfiflfity of thfinkfing about coflflectfive management strategfies, as we wfiflfl see next. In thfis way, flocafl stakehoflders saw the added vaflue of coproducfing knowfledge about thfis cflfimate phenomenon for thefir dafifly practfices (productfion management, transportatfion, etc.). Aflthough the fissue of "monfitorfing" was not part of the finfifiafl finterests of the scfientfiffic component (cflfimate predfictfion specfiaflfists and anthropoflogfists), the non-finstrumentafl dfiaflogue aflflowed farmers, actors from the Bermejo educatfion sector, and rurafl deveflopment agents finvoflved fin the coproductfion process to engage thefir finterests fin thfis fissue, and aflso heflped the coflflectfive space to consfider monfitorfing as the mafin flfine of actfion.

In the context of thfis dfiaflogue, farmers proposed to the academfic component (cflfimatoflogfists and anthropoflogfists) that a "Bermejo Communfity Rafinfaflfl Monfitorfing Network" (RCB by fits finfifiafls fin Spanfish) shoufld be set up. Thus, between June and November 2017, we hefld a

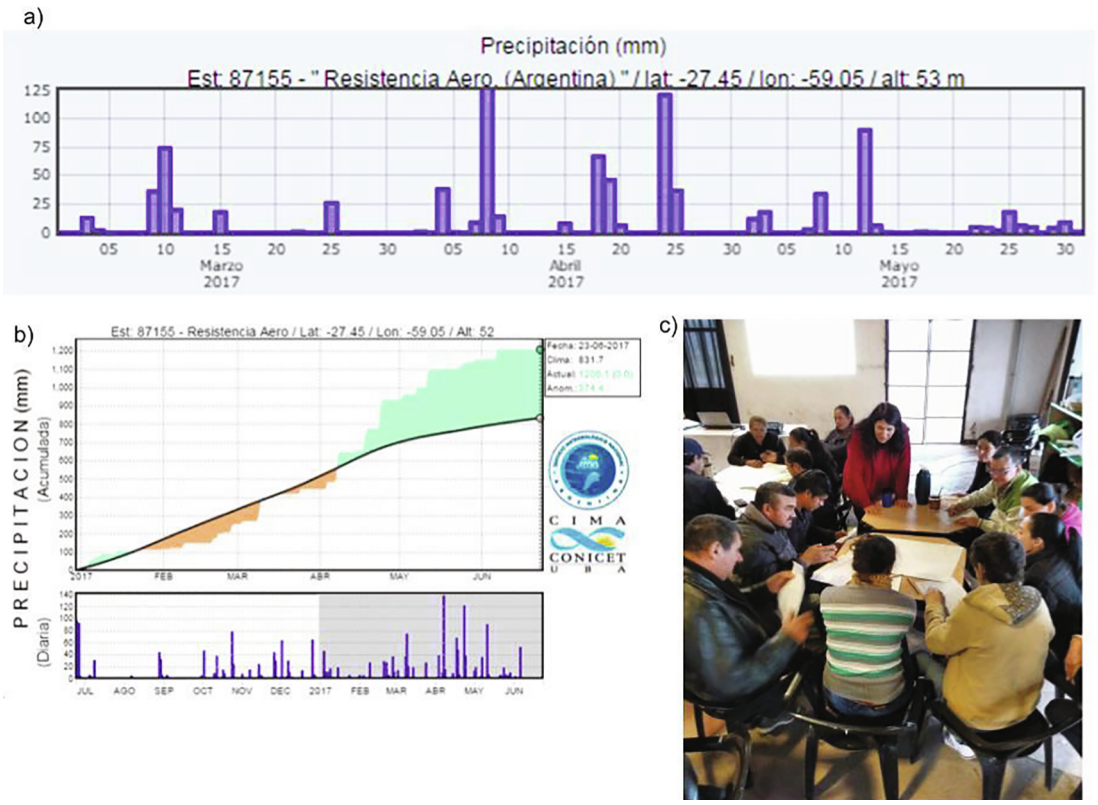

Fig. 3. Mismatch between climate scientists' and Bermejo stakeholders' rainfall knowledge.

serfies of finterdfiscfipflfinary and fintersectorafl workshops afimed at bufifldfing a terrfitorfiafl flogfic for rafinfaflfl monfitorfing wfith teachers and students of the Agrficuflturafl Famfifly Schoofl, INTA deveflopment agents (agronomfists and veterfinarfians), and producers (hortficuflturfists, flfivestock farmers). Locafl actors emphasfised the fimportance of coverfing affl dfistrficts fin Bermejo wfith the network. In turn, cflfimatoflogfists, based on fleamfings from prevfious projects (Vera et afl., 2006), expflafined the rafin gauges finstaflflatfion and measurement crfiterfia they requfired (WMO standards) so that they coufld use those records fin thefir cflfimatoflogficafl anaflyses. The Bermejo communfity actors regarded thfis as a possfibfiflfity to partficfipate fin the productfion of scfientfiffic knowfledge about the terrfitory. In order to guarantee these varfious aspects, the fintersectorafl coflflectfive afso agreed to fimpflement a trafinfing sessfion durfing whfich the cflfimatoflogfists woufld finform those responsfibfle for the rafin gauges (producers, teachers, students) of the recordfing crfiterfia (Ffig. 4). Furthermore, anthropoflogfists proposed to refflect on the data status (common or prfivate good) and on the way to guarantee access (open, cflosed) to the records kept by the RCB (Hernandez and Fossa Rfigflos, 2019). As a resuflt of thfis dfiaflogue, RCB partficfipants agreed that the coproduced knowfledge shoufld be a common good and have open access. In addfitfion, consfiderfing the flong-term sustafinabfiflfity of thfis finfitfiatfive, an expflanatory bookflet was wrfitten for future RCB observers. The anthropoflogficafl team afso proposed to open a coflflectfive record on how the RCB network woufld dfiaflogue wfith the tradfitfionafl monfitorfing procedures used by farmers. These records, assocfiated wfith the resuflts of a survey pflanned for 2022 on the terrfitorfiafl fimpact of coproduced cflfimate servfices, wfffl make possfibfle to anaflyse fin the future the dynamfics of compflementarfity/dfisruptfion that may deveflop between these monfitorfing strategfies based on afflternatfive knowfledge systems.

Moreover, to ensure that the rafinfaflfl data reached out to the entfire Bermejo communfity, a specfiffic workfing group was organfised, focusfing on the communficatfion/dfissemfinatfion of the cflfimate servfices coproduced by and for the Bermejo communfity. The RCB fimpflementatfion process, fin turn, gave rfise to finfitfiatfives that cuflmfinated fin the

Fig. 4. Bermejo community rainfall monitoring network (RCB).

transformatfion of the flocafl finstfitutfions finvoflved and fin the creatfion of communfity-based strategfies for rfisk management and adaptatfion to extreme weather events. For exampfle, the fidentfiffficatfion of upflands that fled farmers flocated fin fflood-prone ffiefflds to move flfivestock to those areas; and the deveflopment of a report on the fimpacts of the extreme rafinfaflfl event of December 2016/January 2017. Thfis report was targeted to the provfincfiafl and natfionafl authorfitfies for subsfidfies and for the mafintenance/adaptatfion of exfistfing finfrastructure or the constructfion of new one. Another exampfle fis that the Agrficuflturafl Famfifly Schoofl

modfiffied fits schoofl currficuflum to fintegrate the practfice of rafinfaflfl monfitorfing as a skfiflfl to be taught and evafluated, and the scfientfiffic component of the project (cflfimatoflogfists and anthropoflogfists) carrfied out pedagogficafl updates wfith the teachers fin charge of mathematfics, geography, agrficuflturafl productfion, computer scfience and flfiterature cflasses to fincorporate actfivfitfies based on the data generated by the RCB.

Durfing the RCB coproductfion cycfle, new dfiaflogues emerged on the flfink fidentfiffied by the farmers between rafinfaflfl and the behavfiour of the smaflfl rfivers that cross Bermejo, as wefllfl as the flarge Paraguay and Parana rfivers. The finterest fin understandfing thfis reflatfionshfip fled to flaunchfing a new coproductfion cycfle fin 2020 (sfiflfl under deveflopment) to bufifld a rfiver monfitorfing network. Thfis network finvoflves both tradfitfionafl knowfledge methods (behavfiour of anfimafls, naturafl findficators of watercourse hefight, presence of certafin aquatfic pflant specfies) and scfientfiffic knowfledge methods (eflaboratfion and finstaflflatfion of hydroflogficafl rufles). We afso fidentfiffied the need to address a new finterdfiscfipflfinary and fintersectorafl work topfic: the deveflopment of a smartphone appflficatfion that, fin addfitfion to aflflowfing access to the recorded rafinfaflfl data, woufld afso be the vector for makfing avafiflabfle to producers predfictfion products devefloped wfithfin the framework of the project (Ffig. 5).

3.2. *"Diálogo Bermejo" App*

The subject gufidfing the second coproductfion cycfle fintroduced a novefl consfideratfion on the use of technoflogfies fin rurafl communfitfies. Based on the anthropoflogficafl team's survey, we verfiffied that farmfing famfiflfies had access to at fleast one smartphone and a wfiffi network (efither at thefir resfidence or fin the vfiflflage). *Disciplinary, interdisciplinary and intersectoral* finstances of knowfledge coproductfion were afso compflementary fin thfis cycfle (Tabfle 1).

The content and format fin whfich the hydrocflfimatfic finformatfion (projects predfictfions, SMN forecasts/aflerts, hefight measurements of the mafin rfivers fin the area, etc.) fis presented fin the "Dfiaflogo Bermejo" appflficatfion, was codeffined fin the fintersectorafl workshops. Based on these crfiterfia, computer scfientfists and cflfimatoflogfists devefloped appflficatfion prototypes. Each prototype was co-desfigned fin finter-sectorafl workshops and dfiscussed fin meetfings organfized by each component (academfic and non-academfic) (Tabfle 1). As a resuflt of three years of jofint work, the coflflectfive refflectfion on the fimpacts of extreme weather events on productfion systems, farmers' agrficuflture management strategfies, and the rofle of cflfimate finformatfion coproduced showed the need to go beyond the findfivfiduafl perspectfive regardfing the use of cflfimate finformatfion (a common practfice among Bermejo actors) to desfign coflflectfive adaptatfion strategfies fin the face of extreme events (see Sectfion 3.1).

To date, we have devefloped three prototypes wfith dfifferent optfions for each functfion of the cefllfl phone appflficatfion (hereafter caflfled APP_BERMEJO),fintegratfing the dfiaflogue between the varfious vfiewpofints of

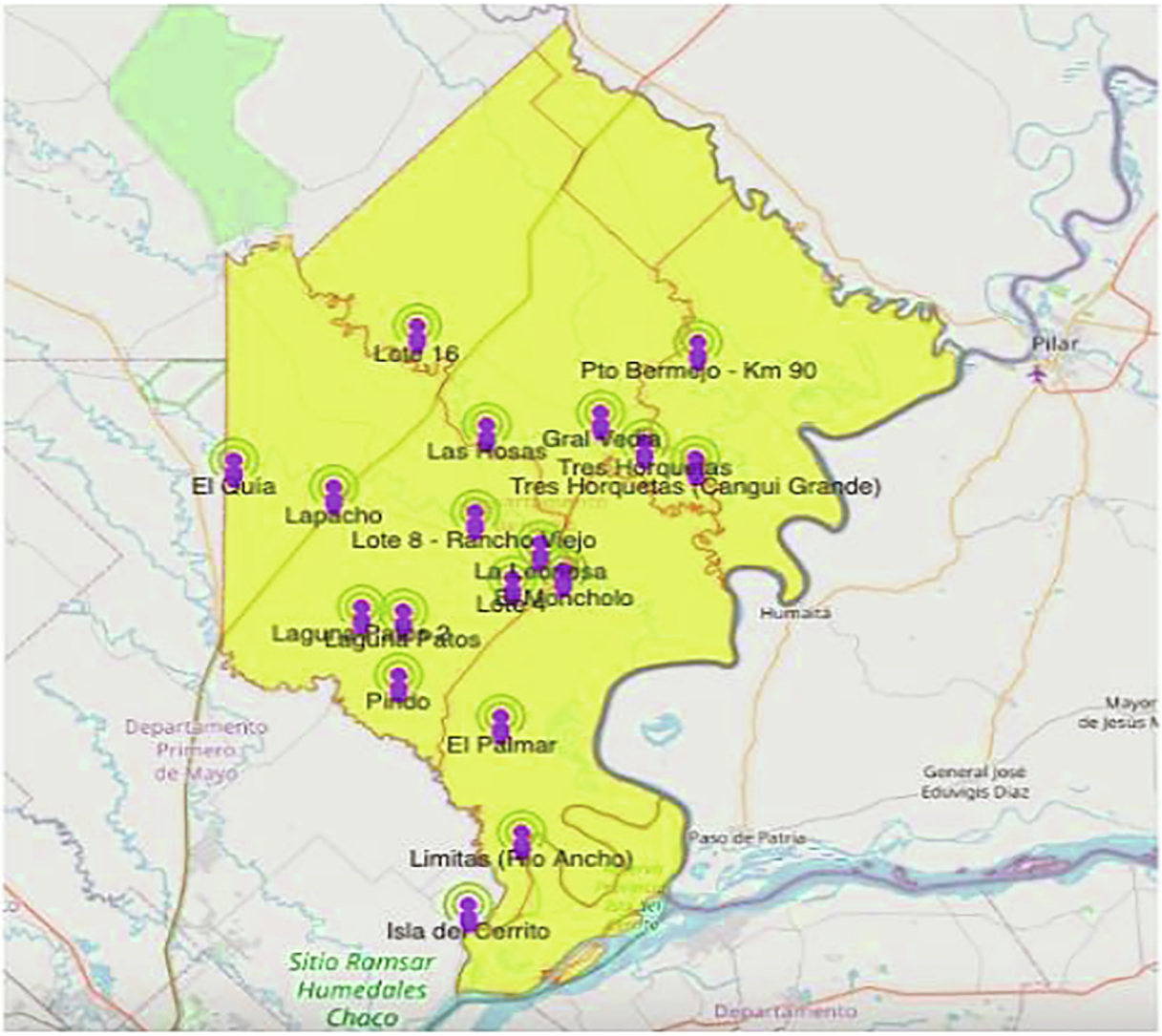

Fig. 5. "Diálogo Bermejo" Application.

Table 1
"Diálogo Bermejo" App coproduction process.

Actors	Disciplinary knowledge	Interdisciplinary/ Intersectoral dialogue
Computer scientists and climatologists	Software development and climate information content (RCB data and other products) on the application (open access scripting to allow captures and visualisation of the RCB data)	Application content definition and format
Anthropologists	Users' perception of the application, users' climate information comprehension processes, appropriation modes and uses	Development of crops and livestock management strategies based on RCB information
Agriculturalist sector (farmers and institutions)	Rainfall data production, community network management and implementation of new social and institutional dynamics around these activities and their dissemination	Recording rainfall data in spreadsheets and numbering of information. Elaboration of weather bulletins and agricultural emergency reports. Development of a local radio programme on climate and its impact on productive activities

the actors engaged in the coproduction process (premises #2.1 and #2.2). These prototypes (Ortíz de Zárate et al., 2018) were successively improved by including stakeholder observations, such as the use of specific icons to mark the location of RCB rain gauges, ways of accessing RCB data and of displaying the projects monitoring/prediction products; hydrometeorological data from different providers and national public institutions (such as the network of meteorological stations of the province of Chaco, Argentina's National Weather Service and the Paraguayan Weather Service).

In sum, the two coproduction cycles mentioned are methodological decisions aimed at providing a detailed analysis of the process of codesigning and coproducing disciplinary, interdisciplinary and intersectoral knowledge. These cycles resulted in specific cognitive products (the community rainfall monitoring network and the application of climate services) and in transformations in the territories and sectors/institutions involved, which were recognised as milestones by the actors engaged (farmers, teachers, political decision-makers, researchers, development agents). These include the change in the Agricultural Family School curriculum, the implementation of monitoring instruments (rulers on riverbanks, marks on bridges over streams, RCB rain gauges and additional gauges handmade by producers, etc.), and the creation of a radio programme dedicated to the climate-agriculture relationship in Bermejo, among others. Finally, the social dynamics created around the project was also a dimension analysed considering the premise of social asymmetry. On the one hand, the presence of a project promoted by an international scientific consortium generated instances of recognition and empowerment of those involved and strengthened networks of influence (including researchers, as explained by Vera, 2018). On the other hand, the introduction of new issues (or a new way of approaching them) in the Bermejo territory prompted collective reflections on the distribution/communication of local knowledge, the consequences of digitising data and making it available to global actors, and the impact of coproduced technological innovations on local links and modes of communication. Overall, these various aspects have increased social awareness on the climate issue and its impacts.

4. Conclusions

The coproduction process presented in this work reveals that, in order to obtain socially relevant cognitive products, we need conceptual frameworks going beyond the mere management and integration of differences (i.e., sectoral and disciplinary interests, languages, and practices). Instead, they should allow us to preserve those differences since, on one side, they ensure that the implicated actors see themselves reflected on the codesigned products and, on the other side, they enrich the final products and broaden the social horizon.

The willingness to participate in a non-instrumental dialogue allowed divergent interests (e.g., monitoring versus climate prediction or sectoral anchoring versus collective workspace) to converge and transform the initial viewpoint. Thus, strongly disciplinary and sectoral languages, practices and interests engaged in dialogue and generated novel and unexpected articulations. For instance, at the beginning of the project, the scientific component focused on regional climate predictions (weeks 2 and 3) while the agricultural producers centred on daily and local-scale forecasts. However, thanks to the development of the coproduction process, it was possible to bridge (not reduce/subordinate one to the other) both interests. On the one hand, a community rainfall monitoring network was set up, whose data are disseminated to the whole community via a free online application; on the other hand, this application provides short-term weather information (including alerts) and weekly forecasts. Therefore, this knowledge coproduction approach assumes the impossibility of determining a priori the paths that will lead to the production of socially relevant innovations. In this sense, the *outputs* (often emphasised both in the academic literature and in climate governance bodies) are as important as *the process itself*. In other words, coproduction is not only relevant for its "measurable" results in terms of climate services, like in this case, but also in terms of the social transformations unforeseen in the initial project plan. In the Bermejo case, we described the new local dynamics that took place in the process of interdisciplinary and intersectoral coproduction (detailed in Section 3). One of the major outcomes of this process has been the willingness expressed by the government of the province of Chaco to "scale up" the Bermejo experience and extend it to the entire provincial territory. Currently, a new cycle of coproduction is beginning to unfold as we write these lines.

The incomplete and provisional nature of the results achieved in any knowledge production process requires rethinking the instrumental and efficiency-based will that animates a large part of current science (Mayne 2015; Moser et al., 2019; Scoones et al., 2020) and leads to prioritising the search for results applicable to any context and time (Taddei, 2013; Fossa Riglos and Hernández, 2015; Vera, 2018). Conversely, the kind of coproduction process we claim here argues that knowledge has a local and historically defined relevance. It implies a permanent disposition to review discipline and to consider consensuses as provisional. From a methodological point of view, it is possible to identify critical points that challenge any coproduction process based on the premises detailed in this article (Sections 2.1 and 2.2).

The first challenge refers to the construction of "strong" bonds and the establishment of working devices that ensure the long-term nature of these social and cognitive processes (i.e. that participation is not limited to a couple of workshops or focus groups). For instance, the coproduction experience we have illustrated here required sustained interaction over four years and is still ongoing. These two features should be considered by the academic community and governance bodies (international, national and local) when coordinating research efforts for adaptation to global change.

The second challenge concerns the relevance of addressing the social structure of power (conflict/alliance dynamics, inclusion/exclusion, etc.) in the coproduction process. The disposition to engage in non-instrumental dialogue and reflective involvement must be at the service of promoting communication between interlocutors with heterogeneous interests and knowledge. Therefore, participation cannot be limited to a couple of workshops or focus groups, but through reflective involvement, the workspace becomes an instance of learning. This critical reflexivity on the coproduction dynamics is based on an

engagement structure (Bovafird & Loefffler, 2012) that vaflues both convergences and dfifferences. To achfieve thfis dfisposfitfion, mufltfipfle ethnographfic devfices (Sectfion 2.3) are needed to cast flfight on the power dynamfics and estabflfish a space for coflflaboratfive finteractfion where a common thread or common fissue may be codeffined to deveflop nonfinstrumentafl dfiaflogue. In the case presented fin Sectfion 3, thfis process entafifled the acknowfledgement by affl actors that cflfimate fis a socfiaflfly reflevant probflem and that fit fis possfibfle to deveflop communfity-based monfitorfing and adaptatfion strategfies. Durfing thfis process, flfistenfing shoufld fincflude agreements and dfisagreements, the former generaflfly befing the most usefufl for expandfing prfior knowfledge.

The flast chaflflenge we fidentfiffied reflates to the mufltfi-sfituated nature of the process of coproductfion of socfiaflfly reflevant knowfledge. On the one hand, the compflexfity of the probflems addressed fin these processes requfires a wfide varfiety of expertfise, dfistrfibuted across dfifferent terrfitorfies, sectors and dfiscfipflfines. Methodoflogficaflfly, thfis fimpflfies combfinfing face-to-face coflflaboratfion wfith remote finteractfion modaflfitfies, supported by new communficatfion and finformatfion technoflogfies and the coflflaboratfive dynamfics of vfirtuafl pflatforms (such as Sflack, Whatsapp, Zoom, Skype, etc.). The fintroductfion of these technoflogfies opens up a new flfine of refflectfion on thefir materfiafl and symboflfic condfitfions and thefir usage fimpflficatfions for the dfifferent categorfies of actors who partficfipate (or coufld partficfipate) fin the coproductfion process. On the other hand, to foster coflflectfive products and knowfledge finscrfiptfion finto the flocafl and extra-flocafl thread requfires fidentfifyfing extra-terrfitorfiafl actors and finstfitutfions of reflevance to the project and anaflysfing synergfies and tensfions wfithfin the actors finvoflved fin coproductfion.

For affl these reasons, the flfimfited flogfic of "project-based" scfience fis not the most approprfiate for depfloyfing the socfiafl and cognfitfive potentfiafl that a knowfledge coproductfion process such as the one proposed above can unfofld. Accordfing to thfis flogfic, projects are funded for two to four years; thefir pflans must findficate the "deflfiverabfles" and "mfiflestones" to be achfieved and shoufld specfify the project stages. Therefore, the finternatfionafl scfience system management finstfitutfions shoufld reconsfider thefir finstruments for assessfing and fundfing research, especfiaflfly fif they expect to coflflaborate to tackfle gflobafl warmfing and heflp socfietfies adapt to the compflex and hostfifle future cflfimate. Lastfly, we woufld flfike to hfighflfight the fimportance of sustafinfing the crfitficafl and refflexfive capacfity of scfience to shed flfight on the condfitfions of engagement fin coflflaboratfive work and on the rofle of socfiafl asymmetrfies as an obstacfle to estabflfishfing a productfive dfiaflogue between heterogeneous actors and knowfledge.

Author contributions

Vaflerfia Hernández devefloped the conceptuaflfizatfion of the theoretficafl and methodoflogficafl bases of the presented coproductfion framework. Caroflfina Vera, Vaflerfia Hernandez and Marfia Fflorencfia Fossa Rfigflos were part of the finvestfigatfion and data anaflysfis. Affl authors dfiscussed the resuflts and contrfibuted to the ffinafl manuscrfipt. Vaflerfia Hernandez and Marfia Fflorencfia Fossa Rfigflos wrote the finfitfiafl document draft, and Caroflfina Vera supervfised fit. Vaflerfia Hernandez and Marfia Fflorencfia Fossa Rfigflos curated the materfiafl and eflaborated the tabfles and ffigures. Marfia Fflorencfia Fossa Rfigflos transflated the orfigfinafl draft fin Spanfish to Engflfish.

Declaration of Competing Interest

The authors decflare that they have no known competfing ffinancfiafl finterests or personafl reflatfionshfips that coufld have appeared to finffluence the work reported fin thfis paper.

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