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Does nature contact in prison improve wellbeing? Mapping land cover to identify the effect of greenspace on self-harm and violence in prisons in England and Wales.

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Does nature contact in prison improve wellbeing? Mapping land cover to identify the effect of greenspace on self-harm and violence in prisons in England and Wales.

This paper presents crucial new evidence that prisons with a higher proportion of the area within their perimeter given over to natural vegetation exhibit lower levels of self-harm and violence (both between prisoners and towards staff). Extending prior qualitative prison-level studies which find that nature contact influences prisoners' self-reported wellbeing, it utilizes GIS mapping to generate a new prison greenspace dataset, capturing – for a cross-section of prisons in England and Wales – the percentage of greenspace within their perimeters. Econometric estimations confirm that greenspace fosters prisoner wellbeing, in that there are lower levels of self-harm and violence in prisons with more greenspace. These relationships are statistically robust, and they persist when we control for prison size, type, age, and level of crowding. These findings are noteworthy in that they both extend understandings of wellbeing in custodial environments, and have the potential to significantly influence future prison design. The paper also provides important new insights demonstrating links between greenspace and wellbeing which have significance beyond the specifics of carceral environments.

Nature contact, carceral geography, prison, wellbeing, greenspace

Introduction

Prison design can have a significant impact on amplifying or mitigating the hardships of imprisonment. Recent qualitative and ethnographic research has brought us closer to understanding the importance of sociophysical environments within prisons (Wener, 2012; Moran and Jewkes, 2015; Moran and Turner, 2019; Moran 2019), in particular the crucial role

played by nature contact. In this paper we therefore test whether prior findings of a connection between greenspace and wellbeing in a small number of prison establishments using mainly qualitative methodologies (e.g. Moran 2019) can be replicated at a larger scale and to a robust degree of statistical significance.

The rise of mass incarceration, and the associated expansion of the carceral estate have attracted widespread and critical academic attention (e.g. Gilmore 2007). Whilst critiquing the structural violence of the punitive state, carceral geographers are also turning their focus to the effects of carceral environments upon those who live, work in, or visit these facilities. This developing literature builds upon research into the restorative characteristics of the built environment in general. Originating with Ulrich's (1984) study of the effects of nature views on patients' recovery from surgery, subsequent work demonstrates the effects of a variety of built environment features on health and wellbeing (see Huisman et al. 2012). Within this literature, nature contact is often identified as a health-enabling element, producing calming effects, reducing stress and tension, and improving health outcomes. Authors have hypothesized about the potentially positive effects of nature contact in prison (e.g. Lindemuth 2007, Reddon and Durante 2019), but until now the evidence base has been limited.

Moore's much-cited 1981 paper reported fewer sickness calls made by prisoners with a view of nature from their cell, and since then knowledge about the impact of nature contact in prison has been advanced through a small number of papers which have reported a connection between nature contact and prisoners' wellbeing. It is important to note that these studies are distinct from the extensive literature on the beneficial effects of prison horticultural programs (e.g. Flagler 1995, Pevec 2006, O'Callaghan et al. 2009), in that they focus *specifically* on the effects of nature contact alone (which may have a generalized effect on prison populations), rather than the associated effects of team working, purposeful activity, physical exertion and so on which also characterize gardening programs (and which tend to deliver these effects only for small numbers of direct participants).

In their experimental study of otherwise entirely nature-deprived solitary-confined prisoners viewing nature videos in one US facility, Nadkarni et al. (2017) found self-reported reductions in negative emotions, as well as reductions in violence and improvements in behavior and communication. Moran and Turner (2019) considered the self-reported effects of nature contact for prisoners in two facilities in the UK and Norway, finding increased feelings of calm. In a study of prisoners in one UK facility, Moran (2019) found that outdoor green spaces and whole-wall photographic images of the natural environment were self-reported to enable restorative effects, and to increase feelings of calm, and the ability to reflect.

Such recent work provides invaluable insights into the self-reported wellbeing (or otherwise) of incarcerated persons. In some cases it advances an explanatory framework for *why* and *how* nature contact may deliver these benefits – e.g. via Attention Restoration Theory which suggests that nature contact reduces mental fatigue (Moran 2019). However, the methodologies used in these studies – frequently interviews or small-scale surveys of incarcerated persons at one or two establishments – mean that their findings, although providing critical insights into experiences in specific contexts, are limited in their transferability. They also lack articulation with broader trends of behaviors such as self-harm, and violence, that both preoccupy prison managers and policymakers, and are arguably visible and troubling symptoms of a widespread lack of wellbeing in custody.

To complement and advance upon this foregoing research, this paper reports a study which sought to determine whether any statistically significant relationship exists between the presence of greenspace – defined as the percentage of vegetated landcover within prison establishments (such as grass, bushes, trees), and self-harm and violence as indicators of lack of wellbeing, using published data from prisons in England and Wales alongside a new dataset generated using GIS software.

This endeavor is purposeful because the inclusion of greenspace in prisons is operationally and conceptually challenging. As Moran and Turner (2019, 64) have noted, “a

triple bottom line of cost, safety and security has meant that UK prisons are comparatively austere, harsh and sterile environments". Public opinion is perceived by policymakers to demand that prison conditions should be worse than those available to low-paid workers outside, with the result that provision of green spaces in UK prisons is severely limited (Moran, Turner and Jewkes 2016). In their study of prison construction in the UK, Moran and Turner (2019) found that green spaces such as lawns, shrubbery or trees were considered expensive to install and maintain, and to pose a potential security risk, either for incidents at height, or for the concealment of contraband. Taken together with a concern that extensive green spaces might look like too much of a "luxury" to the tax payer, their inclusion tended to be minimized. Without robust evidence of the effects of greenspace, these arguments are difficult to counter.

The questions we ask here about the relationship between greenspace and wellbeing in carceral environments offer a unique and distinctive perspective on a much broader issue. There is already a large and growing body of scholarship identifying the potential impact of contact with nature on a range of aspects of human health and wellbeing (Frumkin et al. 2017). Many of these studies, commonly operating at the city or regional scale, involve "exposure science", studying the wellbeing of populations living in areas characterized by differing amounts of greenspace, with adjustment for other potentially confounding characteristics (e.g. Mitchell and Popham 2008). A common limitation in all of these studies is that, as Frumkin et al. note, they define exposure based on the residential environment, an approach "limited by spatial resolution and subject to misclassification if people spend highly variable amounts of time at home" (2017, 5). In other words, studies assume that populations are influenced by the characteristics of their areas of residence, but cannot know with any certainty (unless deploying GPS tracking) how much time people actually spend in those areas, rather than in any other areas they visit which may also influence their wellbeing. This methodological limitation impedes both explanation of causality (e.g. Markevych et al. 2017) and implementation of findings (e.g. Wolch, Byrne and Newell 2014). Although the carceral environment undoubtedly presents its own challenges, by concentrating on incarcerated populations who by definition

experience only the spaces within the perimeter of the prison in which they are confined, we minimize this issue.

Wellbeing in prison

"Wellbeing" is a somewhat nebulous term (Dodge et al. 2012) both in general and in relation to prison, and there are few available datasets that would approximate to a "measurement" of wellbeing across the prison estate of England and Wales, especially if we define it positively rather than contrastively – i.e. as the state of being 'well' or content, as opposed to the absence of some pathology or concern. Although some criminologists have discussed the possibility of human "flourishing" in prison (e.g. Liebling 2012), we are still some way away from a statistical dataset that captures the prevalence of this phenomenon. For the purposes of this project, we enable an approximation of wellbeing through the proxy variables of self-harm and violence, with low levels of self-harm and violence considered to indicate (the presence of) wellbeing, and high levels to indicate lack of, or 'negative' wellbeing. Whatever the specific reasons for self-harming or violent behaviors in prison – and these will of course vary - our contention here is that high levels of self-harm and/or violence are indicative of a lack of wellbeing. In the case of self-harm, there is often an intention to relieve negative emotions, or to "cope" more generally (Smith et al. 2019). In the case of prison violence, negative individual experiences during incarceration, and the conditions of confinement at the level of the institution, play an important role (Levan 2016, Steiner and Wooldredge 2019). Drawing on Sullivan (2015), Moran (2019) argues that stress and violence in prison could be reduced by factors such as nature contact, which reduce levels of mental fatigue that, left unchecked, contribute to poorly controlled impulses, hasty responses and disrespectful interactions. Since this prior study draws a direct connection between nature contact and reductions in stress and violence, self-harm and assault data seem appropriate proxies for a study of the effects of greenspace on wellbeing.

Self-harm and violence have reached record levels in prisons in England and Wales, at considerable cost both financially, and to individuals' welfare (HMIP 2019). There were a record 60,594 incidents of self-harm in the 12 months to June 2019, up 22% from the previous 12 months. The shock of these high numbers can mask the fact that they represent both incarcerated individuals in deep crisis, and prison staff struggling to cope with the impact of witnessing their distress (Walker et al. 2017). The number of self-harm incidents requiring hospital attendance increased by 7% to 3,388 in the 12 months to June 2019 (Ministry of Justice 2019a). Since the average hospital cost per episode of self-harm in the UK stood at £809 in 2017 (Tsiachristas et al. 2017), this small subset of the total incidences of prison self-harm alone costs over £2.7m (without taking into account the additional costs of escort and bedwatch necessary for prisoners to attend hospital). Over the same period there were over thirty thousand incidents of prisoner-on-prisoner assault, and more than ten thousand assaults on staff, both also representing substantial increases over the previous 12 months. The personal and emotional cost to those involved in violent incidents is incalculable, but there are also significant financial implications. Her Majesty's Prison and Probation Service (HMPPS) has not disclosed the full cost of legal action taken by prisoners and prison officers as a result of prison violence, but between 2016 and 2019 it has paid out £85m in litigation claims[i]. Violence is also thought to be an important factor in prison staff turnover[ii]. In the last five years, the cost of training more than 1,700 new prison officers who then proceeded to resign from the prison service within 12 months of commencing employment was reportedly £19.78 million[iii]. Recent record levels of self-harm and violence - widely attributed to reductions in funding and attendant loss of experienced staff[iv] – have seen attention drawn to prison conditions in the UK. In parallel, a drive for a "rehabilitative culture" (Mann, Fitzalan Howard and Tew 2018) has seen a growing desire to comprehend the range of factors that influence wellbeing in custody. Whether fiscally motivated or propelled by a concern for prisoners' welfare, there is undoubtedly a need to understand the significance of the prison environment.

Data and Methodologies

We assembled publicly-available data for all prison sites for over-18s in England and Wales (Immigration Removal Centers and facilities for under-18s were not included) pertaining to incidents of self-harm (HMPPS 2019a), prisoner assaults on staff, and prisoner-on-prisoner assaults (HMPPS 2019b). We also compiled prison-level data over time; data about the age of establishments, their type (their predominant function at the time of data compilation - i.e. for men: Local (holding both short-sentenced prisoners and those awaiting trial or sentencing), High Security/Category A, Category B (medium-high security), Category C (medium-low security), and Open/Category D; Young Offenders' Institutes (YOI) for men aged 18-20; Female prisons, and those specializing in accommodating sex offenders) (HMPPS 2019c), and noted whether they were purpose-built as prisons or converted from other types of buildings such as military bases, orphanages or stately homes)[v]. These data were compiled for all establishments operational at the time of data compilation and analysis. Given the multiple changes in type (e.g. from Cat B to Cat C prison), mergers and other changes to these establishments, especially since 2012,[vi] trends in dependent variables were considered as averages for the period from 2014 (or later for prisons which opened after this date) to 2018. Given the complexity of the prison estate, the data were cleaned for analysis. Where establishments are jointly managed, but physically distinct, they were treated separately. Six prisons with no published date for commencement of operation were excluded. This procedure resulted in an initial dataset covering 111 establishments.

We began our analysis by examining whether and how prison types differ in terms of prisoner wellbeing. Figure 1 shows the prisoner-averaged level of self-harm for the various prison types, averaged for the period 2014-2018.

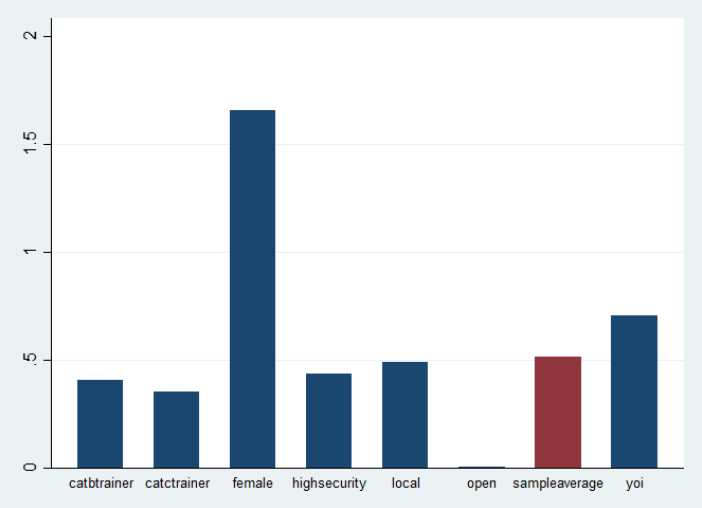

Figure 1 Prisoner-averaged number of self-harm incidents (averaged for 2014-2018)

It is clear from Figure 1 that, as prior research (e.g. Walker & Towl 2016) would suggest, Female prisons are characterized by significantly higher levels of self-harm[vii]. In the period 2014-2018, the average number of self-harm incidents per prisoner amounted to more than 1.5 in this prison type. In stark contrast, Open prisons have much lower occurrences. Figures 2 and 3 compare prison types in relation to prisoner-on-prisoner and prisoner-on-staff assault.

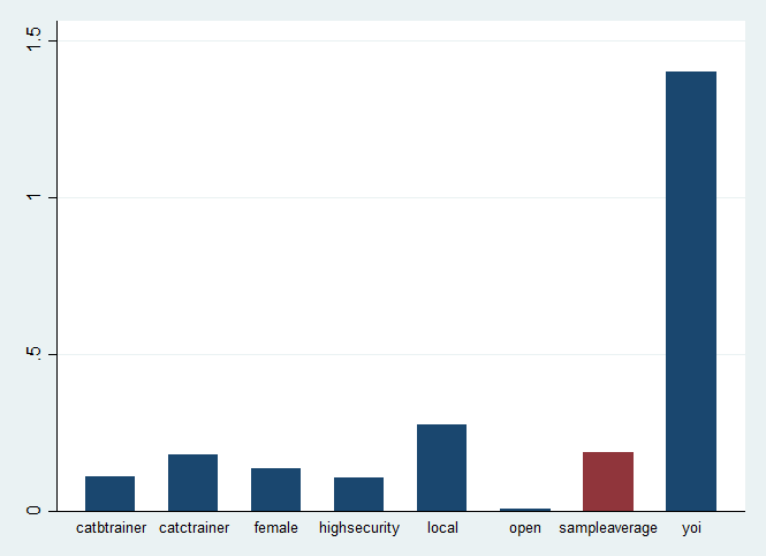

Figure 2 Prisoner-averaged assaults (prisoner-on-prisoner) by prison type (averaged for 2014-2018)

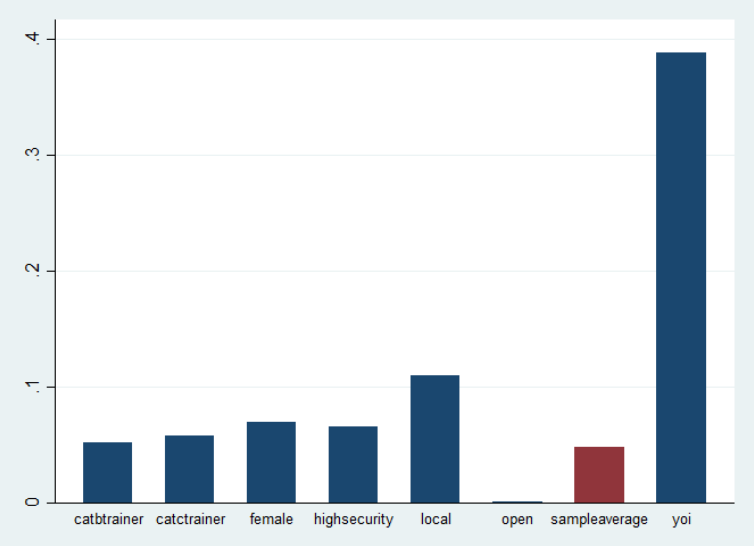

Figure 3 Prisoner-averaged assaults (prisoner-on-staff) by prison types (averaged for 2014-2018)

Bearing out prior research (e.g. Gooch 2019), YOIs show markedly higher levels of assaults of both types, with an average of 1.4 prisoner-on-prisoner assaults, and 0.4 prisoner-on-staff assaults per prisoner in the period 2014-2018 . Open prisons, CatBtrainer and HighSecurity prisons have significantly lower levels of prisoner-on-prisoner assaults than the sample average. Local prisons have a significantly higher level of assaults on staff, whereas CatBtrainer, CatCtrainer and Open prisons have significantly lower levels of such violent incidents.

To further examine how prison types differ in terms of negative wellbeing, we regressed the various indicators of negative wellbeing on a set of prison type dummy variables, taking Local prisons as reference category. The estimated coefficients of the prison type dummy variables capture the difference in the level of self-harm or assaults between Local prisons and the other prison types. Of course, differences between the estimated coefficients then also reflect differences between these various prison types. This approach amounts to estimating:

$$(1)\ Y_i = \beta_0 + \beta_1 CatB_i + \beta_2 CatC_i + \beta_3 Female_i + \beta_4 Highsecurity_i + \beta_5 Open_i + \beta_6\, YOI + \varepsilon_i$$

This regression model posits prisoner wellbeing Y of prison i as a function of the various prison types and an idiosyncratic error term. Y is the number of self-harm incidents, prisoner-on-prisoner assaults or prisoner-on-staff assaults per prisoner, averaged for the period 2014-2018.

The findings are presented in Table 1.

Table 1 Regressing prisoner-averaged negative self-harm indicators on prison types; with Local prisons as reference category

	1	**2**	**3**
Dep. variable	**Self-harm / prisoners**	**Prisoner-on-prisoner assaults / prisoners**	**Prisoner-on-staff assaults / prisoners**
CatBtrainer	-0.06	-0.16**	-0.05*
	(0.09)	(0.08)	(0.03)
CatCtrainer	-0.145**	-0.10**	-0.05**
	(0.06)	(0.04)	(0.02)
Female	1.05***	-0.15	-0.06
	(0.26)	(0.09)	(0.04)
HighSecurity	-0.056	-0.17**	-0.04
	(0.07)	(0.08)	(0.03)
Open	-0.487***	-0.27***	-0.11***
	(0.05)	(0.07)	(0.03)
YOI	0.215	1.13***	0.28***
	(0.17)	(0.08)	(0.03)
F	55.81	42.70	19.91
Adj. R-square	0.53	0.69	0.51
N	111	111	111

*** p<0.01, ** p<0.05, * p<0.10; robust standard errors in parentheses

The findings from regression 1 show clearly that Female prisons have a significantly higher average level of self-harm. CatCtrainer and Open prisons have lower levels of self-harm. Regressions 2 and 3 show that YOIs are characterized by a significantly higher average level of assaults; this is especially the case when we use prisoner-on-prisoner assaults as the negative indicator of prisoner wellbeing. CatCtrainer prisons have a significantly lower level of assaults, as do Open prisons. HighSecurity prisons have a significantly lower level of prisoner-on-prisoner assaults.

Measuring Greenspace

Our purpose in this paper is to identify the effect of the presence of greenspace in prisons on prisoner wellbeing as captured by the proxy variables for lack of wellbeing, whilst allowing for the effect of other prison characteristics. In order to carry out this analysis, we required an indicator of the level of greenspace within the prisons. In the absence of any pre-existing dataset, we devised a GIS methodology to calculate such a greenspace variable.

The Ordnance Survey Mastermap Topography Layer was used as the main source of GIS data. This is a vector map layer with polygons at the building scale (1:1250) that allows for highly accurate analysis of land-use. Polygons labelled as either "multiple" or "natural" in the layer's "make" category were designated as greenspace for the purpose of our analysis. The Mastermap data was sense-checked using 25cm aerial photographs which revealed that the "multiple" category is used for what might be described as non-natural greenspaces such as back gardens and playing fields. These types of green areas are mostly excluded from the OS Mastermap Greenspace Layer, which is why that dataset was not used in this analysis.

Mastermap data and georectified aerial photographs were downloaded for all prisons in England and Wales and imported into ArcGIS. These data are supplied in the British National Grid projection which allows ArcGIS to automatically calculate the number of hectares represented by each polygon within the dataset. To examine greenspace, the outer walls or fences were identified for each prison, using Mastermap data checked against the aerial photographs. This allowed the total area within the prison perimeter to be calculated and compared against the total area of polygons labelled "natural" or "multiple" inside what we termed the 'prison envelope' – thus generating the percentage greenspace data for each prison (Figure 4). Figure 4 depicts the Mastermap Topographic layer showing a prison (upper left); prison perimeter highlighted, with boundary exaggerated for clarity (upper right); polygons within the prison envelope isolated (lower left); all areas of 'natural' and 'multiple' surfaces within the prison wall identified (lower right).

Figure 4 Identifying Greenspace within the Prison Envelope.

Source: Contains OS data © Crown copyright and database right (2020)

Comparing the Mastermap data against aerial photographs enabled us to check the accuracy of the "make" categorization, and confirm, for example, that artificial sports pitches had not been categorized as "multiple" or "natural", and therefore ensure that they had not been designated as greenspace. A small number of additions were made to the greenspace dataset based on a detailed examination of land-use at each prison site using aerial photographs; glasshouses are not included in categories of 'multiple' and 'natural' but were manually added.

The Mastermap and aerial photograph data occasionally diverged, indicating that some features visible on the constantly and incrementally updated Mastermap layers had appeared since the older aerial photographs were taken. The most recent data were used in any such cases, but these divergences suggest that there may unavoidably be minor discrepancies between the exact composition of some prison envelopes during the data span of the dependent variables (2014-18), and at the date of accessing the Mastermap layers (July 2019). However, it is unlikely that any such variations in prison land-use are widespread or significant enough to affect our analysis.

The practicalities of the generation of the 'greenspace' dataset led us to remove Category D/Open prisons from further analysis. (Jointly-managed prisons which included one Open site, and which did not consistently report separate data for each of their constituent sites, were also removed from analysis at this point.) This decision was taken primarily because of the difficulty of delineating these establishments, many of which do not have a physical perimeter wall or fence clearly discernible in satellite images. A further consideration was the intermittent nature of exposure to the prison environment at Open prisons – reminiscent of the challenges of "exposure science" in other contexts (Frumkin et al. 2017). Prisoners at Cat D establishments commonly leave these sites in the morning to undertake employment, returning after work. This means that unlike their counterparts at closed establishments, their wellbeing is likely to be influenced by a range of other settings in addition to the prison itself.

Determining the total area of the prison envelope, and the total area of greenspace within it, enabled us to calculate the greenspace percentage for each prison. Although a high greenspace percentage could be delivered by a low absolute acreage or greenspace, given variation in the absolute size of prison envelopes, this measure was the most appropriate for comparative purposes. The resulting dataset (n=107) is characterized by substantial variation in greenspace percentages, from one prison envelope with no greenspace at all, to more than

75% of another being vegetated. The sample average is 36% greenspace. Incomplete statistical datasets for some of these 107 prisons saw the final number used in regression analysis standing at 103.

Greenspace and wellbeing: empirical findings

To get a first impression of the relation between greenspace and negative wellbeing, Figures 5-7 show scatter plots between the percentage of greenspace and our three indicators of negative prisoner wellbeing.

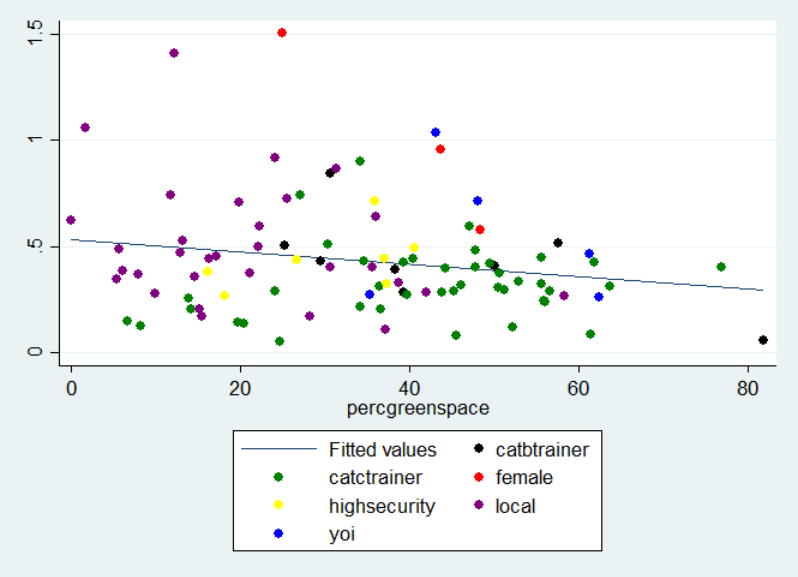

Figure 5. Scatterplot between percentage greenspace and prisoner-averaged level of self-harm

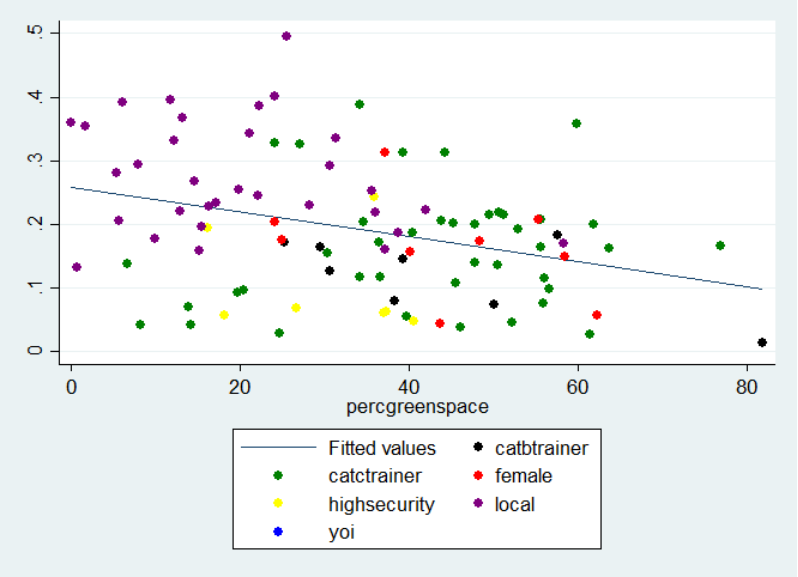

Figure 6. Scatterplot between percentage greenspace and prisoner-averaged level of prisoner-on-prisoner assaults

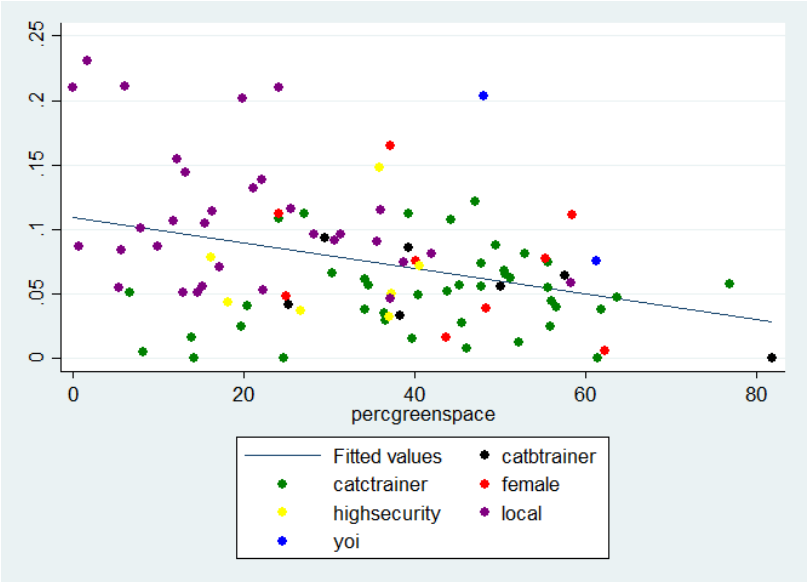

Figure 7. Scatterplot between percentage greenspace and prisoner-averaged level of prisoner-on-staff assaults

The scatterplots between percentage greenspace and self-harm, prisoner-on-prisoner assaults and prisoner-on-staff assaults all show negative associations, suggesting that greenspace may lower negative wellbeing.

Assessing the influence of greenspace on wellbeing

To further analyze these data, we used regression analysis, a powerful statistical method that enables examination of the influence of one or more independent variables on a dependent variable. Although suggestive, the scatterplots that show negative associations between greenspace and negative wellbeing need to be interpreted with caution as they do not control for the impacts of other factors; impacts that may influence the apparent association between greenspace and prisoner wellbeing.

To identify the effect of greenspace in a multivariate framework, we estimate various specifications of the following regression model:

$$(2) \qquad Y_i = \beta_0 + \beta_1 Greenspace_i + \beta_2 Centuryold_i + \beta_3 Opcap\_pop_i + \beta_4 Population_i + \beta_5 Prisontype_i + \beta_6 Sexoffenders_i + \beta_7 Purposebuilt_i + \varepsilon_i$$

where Y is either self-harm (as depicted in Table 2), prisoner-on-prisoner assaults (Table 3) or prisoner-on-staff assaults (Table 4); "Greenspace" is the percentage of greenspace within the prison envelope; "Centuryold" is a dummy variable taking the value of 1 for prisons that first opened in the 19th century (the continued operation of such prisons is somewhat controversial and has been widely criticized)[viii]; "Opcap_pop" is the operational capacity/prisoner population in 2014 (to test whether crowded prisons [where the population is large compared to the operational capacity] are characterized by lower wellbeing)[ix]; "Population" is the log of number of prisoners in 2014; "Prisontype" refers to the dummy variables distinguishing between the different prison types; "Sexoffenders" is a dummy variable capturing specialist sex-offender prisons; and "Purposebuilt" is a dummy variable capturing whether a prison was purpose-built or converted from a previous function (e.g. from a military base, stately home, or orphanage). In this regression analysis, therefore, we are testing for the relationship between greenspace and the other independent variables and the dependent variables of self-harm and violence between prisoners and against staff.

Greenspace and self-harm. Table 2 shows the findings for drivers of self-harm. The estimated effect of the percentage greenspace is significant and negative, indicating that the level of self-harm is lower in prisons with a higher percentage of greenspace. This estimated effect is robust to the inclusion of the other control variables – in other words, the inclusion of other factors describing size, age and type of prisons does not eliminate the impact of greenspace on self-harm, meaning that greenspace reduces self-harm in all types, sizes, ages and origins of prisons and regardless of their level of crowding.[x]

Most of the other control variables are significantly associated with self-harm. The estimated effect of Centuryold is significant and negative, indicating that older prisons have a significantly lower level of self-harm. The estimated effect of operational capacity/prisoner population is also significant and negative, indicating that crowding increases the level of self-harm. The estimated effect of Population is also significant and negative, indicating that prisons with a larger population have lower levels of self-harm. The dummy variable identifying Female prisons carries a significant and positive coefficient, indicating that even after controlling for the effect of the other control variables, this prison type still has a significantly higher level of self-harm compared to the other prison types. Importantly, the dummy variables of the other prison types are not significant when the other control variables are included in the model,; the results that we present in Table 2 are for models that do not include them. The variables identifying sex offender institutions and purpose-built prisons do not carry significant coefficients.

Overall, these findings tell us that even though several prison characteristics are associated with higher or lower levels of self-harm, the negative and significant effect of greenspace on lack of wellbeing – i.e. its propensity to reduce self-harm – remains statistically robust.

Table 2 Drivers of self-harm

	1	2	3	4	5	6	7	Standardized beta
Greenspace	-0.29** (0.14)	-0.53** (0.20)	-0.53** (0.20)	-0.59*** (0.17)	-0.50*** (0.15)	-0.53*** (0.15)	-0.48*** (0.17)	-0.37
Centuryold		-0.15** (0.07)	-0.14** (0.07)	-0.18** (0.07)	-0.13** (0.06)	-0.14** (0.06)	-0.13** (0.06)	-0.26
Opcap_pop			0.03 (0.07)	-0.19** (0.09)	-0.15** (0.08)	-0.15* (0.08)	-0.16** (0.08)	-0.24
Lnpopulation				-0.23*** (0.08)	-0.14** (0.07)	-0.15* (0.07)	-0.14** (0.07)	-0.30
Female prison					0.47** (0.22)	0.46** (0.22)	0.48** (0.22)	0.35
Sex offender						-0.12 (0.08)		
Purpose built							0.03 (0.06)	
F	4.11 (0.04)	3.56 (0.03)	2.29 (0.08)	3.04 (0.02)	4.14 (0.00)	3.97 (0.00)	3.61 (0.00)	
Adj. R square	0.04	0.09	0.09	0.21	0.30	0.32	0.30	
N	95	95	94	91	91	91	91	

*** p<0.01, ** p<0.05, * p<0.10; robust standard errors in parentheses

The findings reported in columns 1-7[xi] indicate by how much the dependent variable changes when the independent variables change by one unit. It is difficult to ascertain the relative importance of these estimated effects, as the variables are measured in different ways. To obtain an indication of relative importance, we re-estimated the model to obtain standardized beta-coefficients, which facilitate such a comparison by indicating by how many standard deviations the dependent variable changes following a one standard deviation change in the independent variables, irrespective of their measurement. Looking at the standardized beta coefficients reported in column 8, the variable greenspace has the largest impact on self-harm, closely followed by the effect of a prison housing only female prisoners.

Greenspace and prisoner-on-prisoner assaults. Table 3 shows the results from estimating the regression model with prisoner-on-prisoner assaults as the dependent variable. Similar to the findings in Table 2, the estimated effect of greenspace is significant and negative, indicating that prisons with more greenspace have a lower level of prisoner-on-prisoner assaults.[xii]

Table 3 Drivers of prisoner-on-prisoner assaults

	1	2	3	4	5	6	7	Standardized beta
Greenspace	-0.20*** (0.05)	-0.22*** (0.06)	-0.24*** (0.05)	-0.22*** (0.05)	-0.29** (0.14)	-0.34** (0.15)	-0.46** (0.16)	-0.17
Centuryold		-0.02 (0.02)	-0.02 (0.02)	-0.015 (0.02)	-0.13** (0.05)	-0.13** (0.05)	-0.12** (0.05)	-0.17
Opcap_pop			-0.05** (0.018)	-0.035 (0.028)	-0.04 (0.10)	-0.05 (0.11)	-0.017 (0.10)	
Lnpopulation				0.02 (0.02)	-0.18** (0.08)	-0.18** (0.08)	-0.16** (0.08)	-0.29
Catbtrain					-0.16*** (0.04)	-0.12*** (0.04)	-0.10** (0.04)	-0.08
Catctrain					-0.13*** (0.04)	-0.10** (0.04)	-0.09** (0.04)	-0.14
Female					-0.29** (0.10)	-0.28** (0.11)	-0.29** (0.11)	-0.21
Highsecurity					-0.23*** (0.06)	-0.22*** (0.06)	-0.20*** (0.06)	-0.15
YOI					0.97*** (0.21)	0.98*** (0.21)	1.02*** (0.19)	0.67
Sexoffenders						-0.15*** (0.04)		-0.10
Purpose built							-0.10* (0.056)	
F	12.86 (0.00)	7.55 (0.00)	11.04 (0.00)	8.72 (0.00)	8.57 (0.00)	9.27 (0.00)	10.17 (0.00)	
Adj. R square	0.11	0.12	0.18	0.19	0.75	0.76	0.77	
N	97	95	95	95	103	103	102	

*** p<0.01, ** p<0.05; robust standard errors in parentheses

The effects of Centuryold, Opcap_pop and Population are sensitive to the inclusion of several prison type dummy variables. Starting from regression (4), the results shown in Table 3[xiii] indicate that older prisons have fewer prisoner-on-prisoner assaults, as do prisons with a large prisoner population. The estimated effect of the use of operational capacity is negative but insignificant in most estimations. Four prison types have a significantly lower level of assaults: Cat B and Cat C trainer prisons, Female prisons and High Security prisons. YOIs have a markedly higher level of assaults. Specialist sex offender prisons have a significantly lower level of assaults, as do prisons that are purpose-built. The last column shows the findings with the standardized beta coefficients. From these findings, we can see that unlike in Table 2 for self-harm, the effects of prison type (YOI and Female) and prison size are relatively more important than the effect of greenspace in determining levels of assaults between prisoners[xiv].

Greenspace and prisoner-on-staff assaults. Table 4 shows the results from regressions with prisoner-on-staff assaults as the dependent variable. The estimated effect of percentage greenspace is negative in all the estimations, but when adding all the control variables and prison type dummy variables, the effect is no longer significant in column 8 (p-value 0.11). The use of operational capacity is significant and carries a negative coefficient, indicating that less crowded prisons have fewer assaults on staff. Cat B and Cat C trainers and High Security prisons also have fewer assaults on staff. YOIs have a higher level of assaults on staff, but this effect becomes insignificant when more control variables are added to the model. Specialist sex offender prisons have a significantly lower level of assaults on staff; purpose-built prisons have a significantly higher level. The last column shows the standardized beta coefficients for the regression with percentage greenspace of column 6. This column shows that just as is the case for the effect on self-harm, greenspace has the largest effect on prisoner-on-staff assaults, followed by Cat C trainer prisons and YOIs. This indicates that although the significance of the estimated effect of greenspace on prisoner-on-staff attacks is somewhat less robust compared to the estimations with self-harm and prisoner-on-prisoner assaults as dependent variables, the importance of the effect of greenspace compared to the effects of the other control variables in Table 4 is still relatively large[xv].

Table 4 Drivers of prisoner-on-staff assaults

	1	2	3	4	5	6	7	8	Standardized beta (of reg. 6)
Greenspace	-0.09*** (0.03)	-0.07** (0.035)	-0.08** (0.03)	-0.09*** (0.03)	-0.08** (0.03)	-0.08** (0.03)	-0.05 (0.034)	-0.06 (0.035)	-0.30
Centuryold		0.009 (0.01)	0.01 (0.01)	0.01 (0.01)	0.003 (0.01)	0.001 (0.01)	0.001 (0.01)	-0.002 (0.01)	
Opcap_pop			-0.03*** (0.01)	-0.05*** (0.015)	-0.03** (0.014)	-0.03** (0.014)	-0.04** (0.014)	-0.04** (0.014)	-0.21
Lnpopulation				-0.018 (0.01)	-0.006 (0.01)	-0.006 (0.01)	-0.01 (0.01)	-0.01 (0.01)	
CatBtrainer					-0.025** (0.12)	-0.02 (0.13)	-0.03*** (0.01)	-0.025** (0.12)	
CatCtrainer					-0.03*** (0.01)	-0.03*** (0.01)	-0.04*** (0.01)	-0.03** (0.01)	-0.28
HighSecurity					-0.03** (0.016)	-0.03** (0.016)	-0.04** (0.016)	-0.04** (0.016)	-0.17
YOI					0.08** (0.04)	0.08** (0.035)	0.06 (0.04)	0.06 (0.04)	0.26
Sexoffenders						-0.03*** (0.01)		-0.025** (0.012)	-0.12
Purpose built							0.02** (0.01)	0.02** (0.01)	
F	7.07 (0.00)	3.54 (0.03)	7.02 (0.00)	5.56 (0.00)	6.59 (0.00)	7.22 (0.00)	6.53 (0.00)	6.80 (0.00)	
Adj. R square	0.09	0.09	0.20	0.22	0.39	0.41	0.42	0.43	
N	100	100	96	96	96	96	95	95	

*** p<0.01, ** p<0.05; robust standard errors in parentheses

Greenspace, self-harm and assault. Finally, considering the three indicators of (lack of) prisoner wellbeing, one could argue that prisoner-on-prisoner and prisoner-on-staff assaults are capturing violence and unrest in prisons *in general*, whereas self-harm is an individual expression of negative wellbeing. In this sense, it might be expected that prisoner-on-prisoner and prisoner-on-staff assaults affect the level of self-harm – in that self-harm might be more likely to take place in a prison characterized by high levels of violence. To identify this effect, we can estimate the following model:

$$(3)\ Y_i = \beta_0 + \beta_1 Greenspace_i + \beta_2 Centuryold_i + \beta_3 Opcap\_pop_i + \beta_4 Population_i + \beta_5 Assaults\_pop_i + \beta_6 Femaleprison_i + \varepsilon_i$$

where Y is average self-harm for the period 2014-2018 and assaults is either prisoner-on-prisoner or prisoner-on-staff assault.

The problem with this regression model is that we know that greenspace affects *both* self-harm and assaults. Furthermore, self-harm may also *itself* influence prisoner-on-prisoner or prisoner-on-staff assaults, in that high levels of self-harm might somehow precipitate violence. The presence of such relationships makes it difficult to obtain an unbiased estimated effect of assaults (whether on other prisoners or on staff) on self-harm. For instance, estimating regression model (3) produces an estimated β_5, which captures the association between assaults and self-harm. However, this association may capture both an effect of assaults on self-harm *and* of self-harm on assaults, making it difficult to interpret the estimated magnitude of the estimated coefficient.

The solution to this problem is to conduct a two-stages least squares estimation, where we instrument the variables of prisoner-on-prisoner or prisoner-on-staff assaults. This allows for the unbiased estimation of the effect of assaults on negative wellbeing measured by self-harm. This amounts to estimating:

$$(4.1)\ Y_i = \beta_0 + \beta_1 Greenspace_i + \beta_2 Centuryold_i + \beta_3 Opcap\_pop_i + \beta_4 Population_i + \beta_5 Assaults\_pop_i + \beta_6 Femaleprison_i + \varepsilon_i$$

$$(4.2)\ Assaults\_pop_i = z_0 + z_1 Greenspace_i + z_2 Centuryold_i + z_3 Opcap\_pop_i + z_4 Population_i + z_5 Femaleprison_i + z_6 W_i + \mu_i$$

where W is/are a (set of) variable(s) associated with prisoner-on-prisoner or prisoner-on-staff assaults but not with self-harm. Based on the findings from Tables 2, 3 and 4 we can use the dummy variables YOI, CatBtrainer and HighSecurity as elements of W. These prison categories are not significantly associated with self-harm, whereas they do influence the level of assaults.

The findings from estimating this system of equations are shown in Table 5. Importantly, the findings persist to indicate that percentage greenspace lowers negative wellbeing as captured by the level of self-harm. Furthermore, both in the OLS and 2SLS estimations prisoner-on-prisoner or prisoner-on-staff assaults increase negative wellbeing, indicating that prisons

characterized by higher levels of violence also experience higher levels of self-harm. The Sargan test statistic of the 2SLS regressions in columns 2 and 4 show that the over-identifying restriction cannot be rejected, indicating that the set of instruments that we use to identify the unbiased effect of assaults on self-harm is appropriate.

Table 5 Drivers of self-harm: adding prisoner-on-prisoner and prisoner-on-staff assaults

OLS and 2SLS estimations

	1	2	3	4
	OLS	2SLS	OLS	2SLS
Greenspace	-0.45*** (0.14)	-0.47*** (0.14)	-0.41*** (0.14)	-0.42*** (0.14)
Prisoner-on-prisoner assaults	0.46*** (0.10)	0.34** (0.14)		
Prisoner-on-staff assaults			2.15*** (0.44)	1.86** (0.64)
Centuryold	-0.10** (0.05)	-0.11** (0.05)	-0.09 (0.05)	-0.09* (0.05)
Opcap_pop	-0.17** (0.07)	-0.17** (0.07)	-0.15** (0.07)	-0.15** (0.06)
Lnpopulation	-0.08 (0.05)	-0.10** (0.05)	-0.08 (0.05)	-0.09* (0.05)
Female prison	0.60*** (0.13)	0.57*** (0.13)	0.65*** (0.13)	0.63*** (0.13)
Goodness of fit	11.47	54.94	11.75	58.42
Adj. R square	0.41	0.44	0.42	0.45
F first stage		10.11		8.79
Adj. R square first stage		0.48		0.44
Sargan		4.17 (0.25)		2.18 (0.54)
N	91	91	91	91

*** p<0.01, ** p<0.05; robust standard errors in parentheses

Overall, the collection of findings in Tables 2-4 all show that greenspace lowers negative wellbeing, whether measured by self-harm, prisoner-on-prisoner assaults or prisoner-on-staff assaults. The added value of Table 5 is in providing a cause-and-effect analysis that shows that prisoner-on-prisoner assaults and prisoner-on-staff assaults both increase the level of self-harm. This indicates that greenspace *not only* has a direct effect on self-harm and prisoner assaults *but also* an indirect effect running via prisoner assaults to self-harm.

Conclusions

Previous studies have suggested a potential link between nature contact and improved wellbeing in individual prisons, but because of their small scale and qualitative measures, these findings were not generalizable. Our analysis provides the first robust, statistically significant evidence that the presence of greenspace has a measurable impact on wellbeing. This evidence has major implications for prison design and policy, and could positively influence the wellbeing of incarcerated individuals who are currently counted in their millions worldwide.

The specific effects of greenspace on the dependent variables used as proxies for (lack of) wellbeing – self-harm and violence between prisoners and against staff – are also noteworthy. Prison systems vary in their punitive philosophy, the size and types of establishments, and their modes of operation, but even if a highly punitive penal philosophy meant that *prisoner* wellbeing was not *itself* a policy objective, it is widely accepted, across prison systems internationally, that self-harm and violence in prisons have severe financial consequences, and implications for the wellbeing and retention of prison staff. These findings are generalizable in that whether improvements in prisoner wellbeing are sought as part of a humane and rehabilitative prison system, or simply as a means to manage the financial cost and staff attrition associated with self-harm and violence, inclusion of greenspace should be a key element of design of new prisons, and existing prisons should have the space within their perimeters 'greened' via planting of vegetation wherever possible.

Our findings also open avenues for further exploration. In the absence of a national-level dataset that could serve as a measurement of positive wellbeing in prison, we used self-harm and violence data as proxies for *lack* of wellbeing. If such a database can be generated, there is clearly scope for this analysis to be repeated and for these findings to be tested using such data measuring wellbeing positively, rather than as the absence of 'ill-being'.

The strength of this study is in its macro-level analysis, progressing beyond the single-facility studies of nature contact in prison which have taken place so far. A disadvantage of this

approach, though, is that we implicitly assume that all prison residents at each establishment have equal opportunity to benefit from any greenspace present within the prison envelope. (Recalling to a far lesser extent the limitations of "exposure science" in general.) Given varied prison layouts, and the different views afforded from different accommodation units, this is unlikely to be the case. In other words, we cannot determine in this study what the views from individual cells might be, how often incarcerated persons might otherwise see green spaces which are out of sight from their accommodation units (for example while moving from one part of the prison to another), or whether some prisoners might have a view to green space beyond the prison perimeter (for example if they have a view over the prison wall). In further work (Authors et al, forthcoming) we explore such effects of green space beyond the prison perimeter, and future work could productively explore the differential effects of different views..

In the analysis we also implicitly assume that all prisoners are equally sensitive to the impact of greenspace, whereas it is possible that its effects depend to an extent on prisoner characteristics, which (other than gender and sex-offender status, by virtue of prison type) we do not consider here. There is some evidence of gender differences in the positive health outcomes associated with access to natural environments (Richardson and Mitchell, 2010), and there may also be differential benefits for different socioeconomic and ethnic groups (Ruijsbroek et al. 2017, Browning and Rogolon 2018). Our findings suggest that further research at individual prisons could usefully explore whether levels of wellbeing vary according to the accessibility or visibility of greenspace, and the characteristics of prisoner populations.

Our study was motivated specifically by a desire to understand *prisoner* wellbeing, but our final reflection is on the potential for the carceral environment to enable interrogation of broader questions about greenspace and wellbeing. By studying a confined population (and by excluding Open prisons from analysis) we have largely avoided the conventional limitation of exposure science associated with the mobility of study populations. This perhaps suggests that carceral spaces may represent an informative context for greenspace/wellbeing research in

general. Prisons may also be considered a potential setting for typically challenging experimental research design, in which different study populations have different levels of exposure to greenspace, whilst other conditions remain constant. Given the close management of the details of daily life, and specifically mobility, in prison, such experimental comparisons may potentially be feasible. Prisons may therefore be considered "almost ideal environments to conduct research with relatively stable captive populations" (Spencer 2017, 974). However, any such use of prisons - and by extension prisoners – must be considered with caution. Imprisoned populations are not 'typical': ethnic minorities are usually over-represented, males predominate; levels of education tend to be lower, and levels of drug use and mental ill-health to be higher, than the average for the general population (Mears and Cochran 2018). But more importantly, the ethics of exploiting the very captivity that defines imprisonment must be very carefully considered.

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[ix] Since our analysis considers the average level of self-harm or assaults for the period 2014-2018, we calculate the control variables at the start of that period where possible.

[x] Using the sample mean values of self-harm and greenspace, a 10% increase in greenspace would result in a 3.5% reduction in prisoner self-harm.

[xi] The estimations in Table 2 are affected by outliers, which is unsurprising given the heterogeneous nature of the sample of prisons. We omitted some observations after visual inspection of partial scatter plots that we made after each of the regressions – hence the number of observations varies across the columns of the Table.

[xii] Using the mean values of percentage greenspace and prisoner-on-prisoner assaults, the estimated coefficient in column 8 implies that a 10% increase in greenspace would reduce assaults by 6.6%

[xiii] The same issue of outliers noted for Table 2 applies to Table 3; however, with prisoner-on-prisoner attacks as dependent variable the re-inclusion of several prison category dummies corrects for the problem of outliers.

[xiv] Given the number of observations, the number of control variables is large in some of the estimations, such as in columns 6 and 7. We report these results primarily to show that the estimated effect of the variable percentage greenspace is unaffected by the inclusion of these various control variables.

[xv] The estimated coefficient of greenspace in column 6 implies that a 10% increase in greenspace would reduce prisoner-on-staff assaults by 3.2%.